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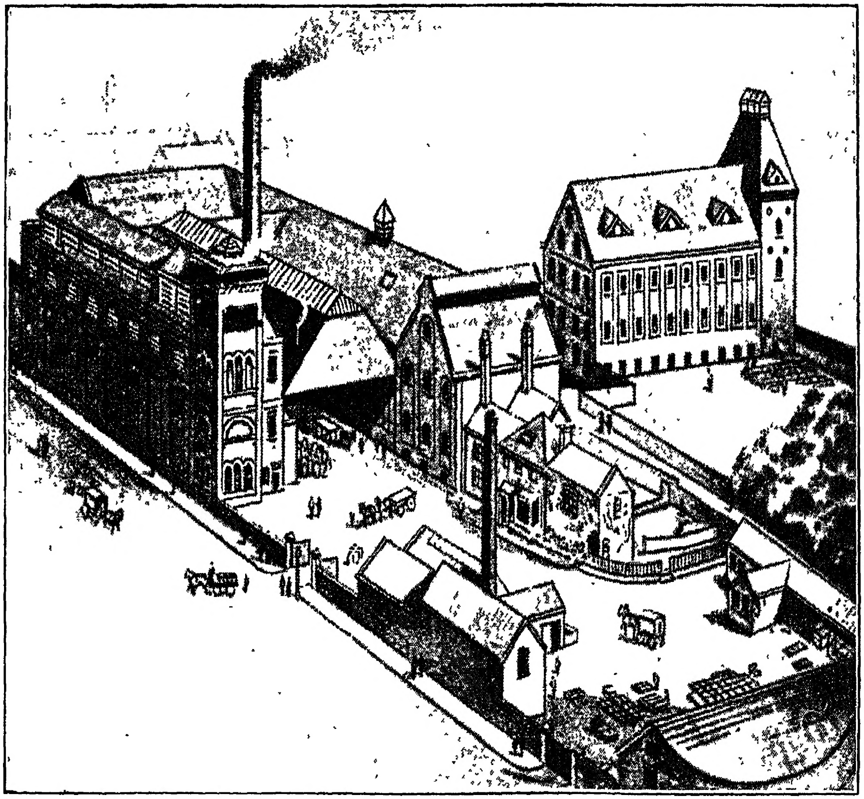

A BRITISH BREWERY AND MALTINGS

Frontispiece

BREWING AND MALTING

BY

J. ROSS-MACKENZIE

F.C.S., F.R.M.S.

SCIENTIFIC AND TECHNICAL EDITOR, "THE BREWER AND WINE MERCHANT AND BREWER'S GUARDIAN," LONDON

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PREFACE TO SECOND EDITION

THE success of *Brewing and Malting*, inferred from the necessity to issue a Second Edition of this popular work in so short a space of time since the initial publication of the work, is very gratifying.

I have thoroughly revised and augmented, where necessary, the original contents in order to bring the volume up to date, and the numerous subjects dealt with include: modern methods of water manipulation ; the functions of prepared Malt Extract as a valuable brewing auxiliary ; practical examples of Parti-gyle calculations ; standardization of beer colours ; and the Polarimeter and its application in the brewery.

In regard to the question of standardization of brewery produce, the most noteworthy recent discovery is the successful application of a new scientific principle in purifying, heating, or cooling the air in breweries. This system will be found fully described herein.

Every endeavour has been put forth to render the present issue even more interesting and concisely informative than the original *Brewing and Malting*, and if my efforts meet with the success which attended the publication of the first edition, then I am amply rewarded.

J. ROSS-MACKENZIE.

WORCESTER,
January, 1926.

PREFACE TO FIRST EDITION

"OSIRIS also invented the beverage made from barley called Beer, which in taste and flavour is not much inferior to Wine. He taught its preparation to those whose country is unsuited for the cultivation of the vine."

—*Diodor. Sic. IV, 2.*

"No man denies that best things may be abused, but what does most harm in the abusing, used rightly does most good. And such a good to take away from honest men, for being abused by such as abuse all things, is the greatest abuse of all."

—*John Milton.*

I HAVE endeavoured in the following pages to present to the general reader and the brewing student an interesting and concise narrative couched in simple language, free from abstruse technicalities, of the general scientific principles upon which the practice of modern brewing and malting is based, together with a description of the various manufacturing processes. It is hoped that a study of this volume will dispel, in some measure, the illusions associated with the alleged mysteries of the brewing craft which have prevailed for generations; that a better understanding will be gained, and, in consequence, a higher appreciation formed of the importance of Brewing as a national industry, and of the purity of the constituents of beers, which Professor H. E. Armstrong, the eminent chemist, pronounced to be "the only safe drink at the disposal of the public."

There has been no lack of literature throughout the ages devoted to tracing the origin of beer and reviewing the history of brewing from prehistoric times, the most recent contribution of importance on the subject being the exhaustive critical essay by Mr. J. P. Arnold, of Chicago. The source of primitive brewing is enshrouded in the mists of antiquity, and the history of beer (*cerevisiae,* from *ceres,* the goddess of corn, and *vis,* strength) and that of the evolution of man is concurrent. The

art of brewing lay neglected for about 1,000 years after the decline of Egyptian civilization, and was revived by the large monasteries to provide entertainment and wholesome nourishment for pilgrims. Brewing subsequently extended considerably in the production of beer in households, and on a vaster scale for sale, until, with the passing of the unenlightened days of empiricism and the advent of brewing science and technology, the industries of malting and brewing gained in prestige until they reached the position of power and high standard of importance these industries now hold in the social and economic life of the nation, as the producers of commodities for which there is no substitute and which are regarded by workers of all classes as necessities.

Beer only contains an infinitesimal proportion of alcohol (from 3 to 5 per cent), and it is only beverages of this class that promote good fellowship, sociability, and the interchange of ideas.

An essential constituent of dietary is vitamins, in the absence of which perfect nutrition is unobtainable. Yeast and beer contain vitamins, a factor which contributes its share to the unassailable popularity of beer as a nutritive, sustaining and refreshing beverage. Excerpts from the speeches and writings of international publicists and dietetic authorities prove conclusively that beer is a food " to be reckoned as in the first class of carbohydrate (cereal) nutriments."

Dr. John Campbell, B.Sc., Advisory Expert, Ministry of Food, wrote : " The fact is that a glass of good ale is approximately as nourishing as a glass of milk, and that a quart of good beer is nearly equivalent to a quarter of a pound of bread. Nearly the whole of this nutriment is in predigested form ready for immediate assimilation."

In response to an appeal during the war, the Government appointed a committee of the Royal Society in 1917 to report in respect to the economy in the food supply of the nation which might be effected by the

prohibition of brewing. The conclusions arrived at were summarized as follows—

"The beer, together with the milk, contains indirectly from the by-products of the brewery (2 lb. of mixed by-products yield 1·07 lb. of milk) 28 per cent and 59 per cent of the energy, and less than 27 per cent of the protein of the original material, whereas if these materials were not brewed, but utilized in the theoretically best possible manner, about 71 per cent of the energy and 68 per cent of the protein would be recovered as human food. But this very high recovery is possible only if the use of the barley and other materials as food for live stock is equally prohibited. *If, as would otherwise be the case, they were converted into meat, only* 15 *per cent of the energy and* 17 *per cent of the protein would be realized as human food.*"

Professor A. D. Waller, University of London, writing in *The Times*, said: "The food value of beer (plus milk and meat for cattle food) is more than half of the brewing materials used, whereas the food value of the pig meat is less than one-fifth of the same materials. In the form of beer (plus milk, etc., for cattle food) we receive upwards of 2 billion calories, whereas in the form of pig meat we should receive at most 0·8 billion calories—60 per cent of the original beer value by the utilization of beer materials for pig feeding."

Brewing contributes a considerably greater proportion of revenue to the National Exchequer than any other industry. Beer duty alone amounts to the colossal sum of £135,000,000 per annum, or £370,000 per day (including Sundays). Added to the duty on other alcoholic liquors, together with the sums derived from licences and other taxes, the grand total which is derived from alcoholic beverages reaches £300,000,000.

Indeed, brewery companies now function as unpaid tax collectors, as trading reports published show that for every £1 earned by them the State receives from £7 to £10, or nearly one-third of the £950,000,000 originally stipulated for in the 1921-22 Budget.

I have to acknowledge my indebtedness to the publishers of the *Brewer and Wine Merchant and Brewer's Guardian* and *The Brewers' Journal* for their kind permission to draw upon, to some extent, my articles in these periodicals; to my son for drawings of yeasts and bacteria, etc.; and also to the several firms who have lent blocks for the illustrations.

J. ROSS-MACKENZIE.

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BREWING AND MALTING

CHAPTER I

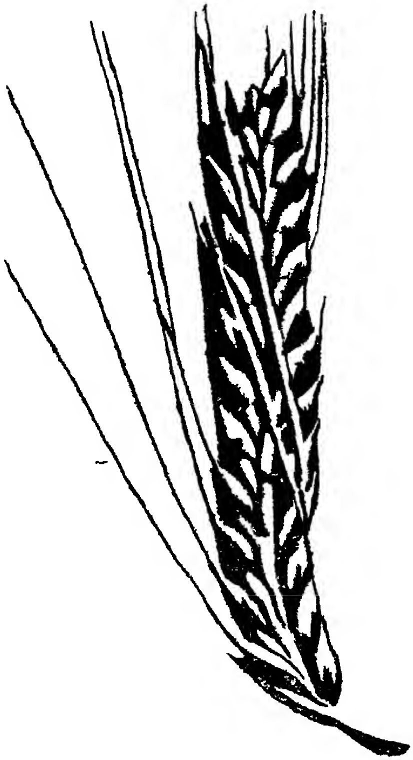
MALTING

WHEN barley is subjected at controlled temperatures to the various processes of steeping, germination, withering and subsequently to drying and curing on a kiln the resultant product is termed malt, the extract from which constitutes the basis and essential ingredient of beer. Malting therefore is an important industry subsidiary to Brewing, and it follows that a brewer's training is regarded as incomplete unless it includes the acquisition of practical experience in the working methods of modern maltings together with a knowledge of the scientific principles underlying the manufacture of malt, which is principally a series of biological processes.

Malting is mainly carried on in barley growing areas by two classes of maltsters, i.e. " Maltsters for Sale " and " Maltster-Brewers." The former trade classification refers to firms or companies whose business is confined to the production of malt for sale to brewers, while the latter appellation is applied in trade parlance and in official phraseology to brewers who manufacture malt for use in their own breweries.

Barley. Regarded botanically as belonging to the order of Gramineae or Grasses and given the specific name of *hordeum sativum* ; numerous species and sub-species of barley are obtainable under various generic botanical terms. The species *hordeum vulgare*, as the name implies, is most commonly met with, and this type includes a number of varieties which have been classified in groups according to the arrangements of the grain on the spikelets of the growing corn. That is

to say, the cereal may develop in the ear in two, four, or six rows ; hence, for instance, the title "two-rowed barley" (*hordeum distichum*) or "Chevallier," from its original cultivation by the Rev. John Chevallier, and "Goldthorpe."



R.J.R. MC.K.

CHEVALLIER BARLEY (HORDEUM DISTICHUM)

Barley described as of "malting-quality" is the distinguishing mark applied commercially and technically to grain of special type, of the highest standard and of maximum germinative capacity. The necessary physical characteristics of barley to ensure satisfactory germination are : Plump grains uniform in size ; the absence of excess moisture ; true ripeness indicated by a pale golden colour ; evidence of a natural "sweat"

or correct maturing period in the rick from the crinkled condition of the husk ; a sweet smell, in contrast to a disagreeable decayed odour arising from the action of mould or other disease producing micro-organisms in the presence of moisture in undue amount, so that the barley reaches the maltster free from the heated and discoloured corns of doubtful vitality.

So far as the British climate with its lack of sunshine and low ripening power is capable of producing a barley possessing the "condition" named, varieties of two-rowed Chevalliers, Goldthorpe, Archer and Standwell are the best examples. Goldthorpe barley can be distinguished from Chevallier, as the former contains a dimple at the top end of the corn, whereas Chevallier is slightly turned towards the end of the corn. Goldthorpes are grown on heavy soil, and are cultivated principally in Scotland and Yorkshire. Archer and Archer-Spratt barley hails from the eastern counties and ripens later than other classes. Standwell barley is of the Goldthorpe type.

Of foreign barleys, to name a few, Brewing Californian is a six-rowed barley, and Chevallier Californian is a two-rowed. Ouchac barley (from Asia Minor) is also a two-rowed cereal, and in normal times it is imported from Smyrna Port. There are two kinds, black and white, and white. France exports two-rowed barley, of which Escourgeon is imported from the North of France and Belgium. Some of the best Continentals belong to a type known as Hanna.

Before 1914 maltsters were in a position to draw supplies from every barley growing country in the world, and will doubtless be in a position to do so again, but up to the 1925-26 season the choice of foreign barleys still remained below the pre-war selection. As yet, however, the sources of supply are limited to importations from California, Oregon, Chili, Morocco, Asia Minor (Ouchak), Smyrna, and Karachi (Indian). India for many years exported millions of quarters of barley to this country. Two varieties are obtained, as already

indicated, from the Pacific Coast, i.e. "Chevallier" and "Brewing," and the same types reach us from Chili. In the majority of instances imported barley is an admixture of two, four, and six-rowed species. In purchasing foreign grown grain of "malting quality" the maltster has the satisfaction of knowing that he can rely upon securing a higher degree of germinative capacity, as supplies from the principal barley growing areas abroad receive the inestimable advantage of a plentitude of sunshine for ripening compared with the barley harvested at home, and, in consequence, foreign barley is more uniform in respect to ripeness and maturity, and invariably exhibits a greater freedom from heated and diseased corns.

Apart from these considerations both British and foreign barleys are employed for conversion into malt for other reasons. Each class of cereal fulfils a definite purpose in brewing, and, as will be explained later, each requires different treatment throughout the various malting processes to secure the result desired.

CHAPTER II

MALTING PRACTICE

MODERN malting methods are based on a scientific understanding of the life history of the barley grain, and the conditions which create alterations in its cell structure and contents by the secretion and development of Enzymes formerly regarded as "unorganized ferments" now defined as Catalysts produced by living organisms. Catalysis is the term applied to mediums which have the property of producing changes without themselves being affected or, in other words, the chemical composition of these catalytic agents is unchanged on completion of the reaction process. This brief explanation should be borne in mind later on in connection with the subject of brewing.

The initial stages of malting practice are intended to secure a cleaner and graded material. To effect the first, rotating or, on the other hand, shaking screens are employed which separate out the chaff and extraneous matter, and drive off the germ-laden dust present in a loose condition attached to the barley. As the dust contains bacteria, wild yeasts, and the spores of mould, precautions are observed to prevent the foul air dissipated by the fans from gaining access to that portion of the building where the germination of the barley is proceeding.

To obtain grain of a more uniform size the barley is graded by being passed over the screens already named, and the power-driven machine which is used serves the dual purpose of cleaning and grading.

British barley, especially in wet seasons, is in a more or less degree deficient in that quality of true ripeness which is necessary to ensure a subsequent satisfactory germination. Many samples contain a moisture content of 15 to 17 per cent. and after the grain has been cleaned

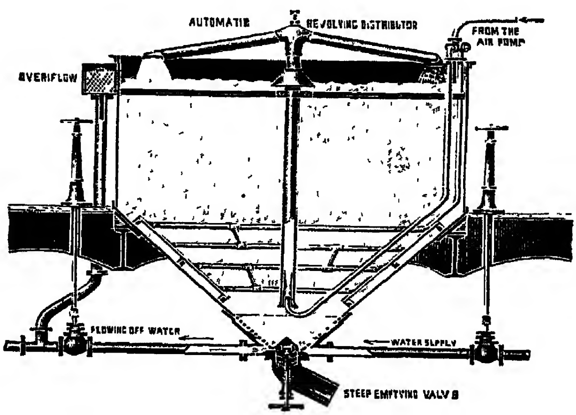
and graded in the manner briefly described, it is subjected to what may be termed an artificial ripening process on the kiln, or "sweating." This consists of placing the barley on the kiln for some 24 hours during which period a temperature of 90° to 120° F. is maintained and the grain turned with shovels about every 6 hours. Barley which has been harvested for some months undergoes a natural maturing, with a reduction of moisture, in the rick, so that "sweating" on the kiln is not applied in general to barley purchased after Christmas. Some maltsters, however, kiln-dry barley, the moisture content of which may from an analytical determination appear satisfactory. They argue that natural maturation in rick cannot reduce the water present in every corn to the uniform level achieved artificially by the "sweating" process on the kiln.

Certain it is that this procedure applied to all British barley improves the germinative power, although the labour involved in handling heavy material is considerable. On unloading from the kiln the barley must be stored from 4 to 6 weeks prior to passing it forward for malting, otherwise germination will be defective. Untreated barley may become heated in store, but correctly treated grain can be carried over from one season to another without its germinative capacity being appreciably affected.

It should be noted that kiln-drying is seldom rendered necessary or is resorted to in the case of foreign barley, as areas abroad cultivating barley of malting type are more favoured in regard to the ripening influence of pure and higher atmospheric temperatures.

Arrangement of Malthouse Procedure. As will be explained later germination is carried on within a comparative limited range of temperature on the original floor system, and it is impossible therefore to continue working during the summer months, the season commencing about the middle of August and ending towards the close of May, or earlier. The foreign barley required

is malted during the warmer months of the beginning and the end of the season, as they are less affected by higher germinating temperatures. Between this period mild ale and porter malts are manufactured, leaving the colder winter months for the production of malts of the highest class employed for pale and export ales.



CONICAL STEEP, WITH WASHING, AERATING, AND MIXING APPARATUS

Steeping. This is the term applied to the soaking in water of the barley in a cistern or steep until saturation has occurred to a degree which will give rise to what is really biological changes in the plant, subsequently producing germination. The duration of steeping varies considerably and is dependent upon various factors among which are the following—

(1) Barley absorbs a soft water with greater avidity than it does a hard water.

(2) Except in the case of the finest quality of Pacific Coast growth, the husk of foreign grown barley is stouter and of a coarser texture than the outer covering of British grain, which therefore requires a shorter steeping period than its overseas rival.

(3) The barley harvested in a dry season requires a longer soaking than the produce of a wet season,

(4) Aeration of the water employed prior to its being carried through the grain in the cistern, together with frequent changes of water, lessens the time required for saturation. Water of ordinary potable quality serves efficiently, but if the temperature is low fewer changes are necessitated, and if the temperature of the water is above 58° F. then more frequent renewals become imperative.

Generally speaking, the total area required for barley steeping cisterns is 14 to 15 feet per quarter of grain, the original steeping liquor occupying two-thirds of the total capacity of the average vessel, and the water is run in to this depth prior to adding the barley. Although the grain has previously undergone the preliminary dressing and screening while dry, as already described, it is subjected to a further cleansing by continuous rinsing while steeping is proceeding, which washes the barley free from surface dust and mould spores in a manner unattainable by machinery. These extraneous matters rise to the surface of the water and are skimmed off. The water is renewed every 12 to 18 hours, the supply being obtained, in the case of ordinary "steeps," from a perforated pipe fixed on the ceiling horizontally and running the entire length of the cistern. Aeration is by this means secured readily and efficiently. The question of long period versus short period steepings primarily depends upon whether the grain receives sufficient aeration by the method described and through the agency of repeated changes of water, and also in a minor measure whether the water employed is soft or hard. The duration of steeping varies each season with the type and condition of the barley harvested, but 60 hours may be taken as a minimum for British barleys, and 75 hours for those of foreign origin, while some tough stemmed varieties of the latter occupy up to 100 hours in the cistern.

Undernoted are physical signs of sufficient steeping of the barley grain—

(1) When cutting through the grain the contents

should be uniformly wetted, except a minute speck in the centre.

(2) When a barley grain is placed between the thumb and the index finger and pressed, the kernel should not prick the skin.

(3) The kernel should be sufficiently elastic to be bent over the finger without breaking.

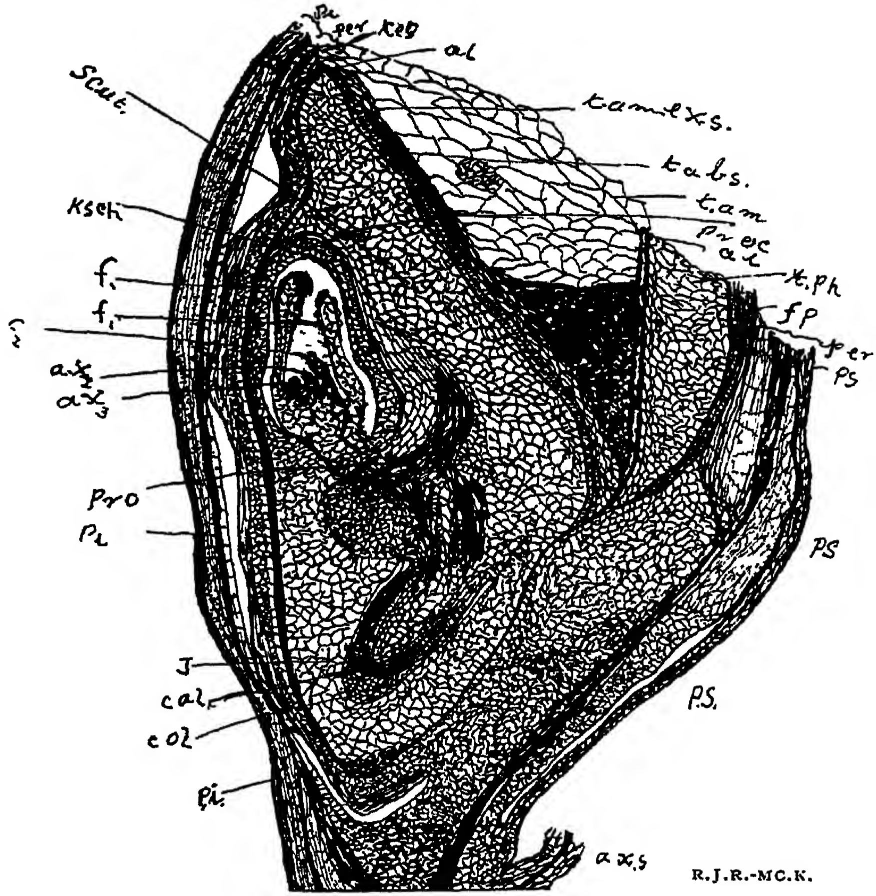
(4) At the end where the radicle is located the hull should appear to open.

(5) Upon biting gently into a kernel the contents of the grain should move to both sides without breaking or cracking of barley. During steeping the grain absorbs water equal to 50 per cent of its own weight. Well drained barley should leave the steep with a moisture percentage not exceeding 44.

Couching. This is the intermediate or "nursing" stage between the germinating floors and the cistern or steep. When emptied from the latter vessel to the "couch" the grain is allowed to remain there at a depth of not less than 2 ft. 6 in. or more than 4 ft. regulated according to the season of the year and the temperature of the barley, which should reach 54° F. before the expiration of 24 hours from "casting" or "throwing out," when the rootlets should make their appearance. In the event of the temperature named being recorded earlier, then the barley which now has commenced to germinate is turned with malting shovels and carried forward to the malting floor where it remains at a depth of approximately two-thirds of that originally occupied in the couch.

To understand the morphological changes which occur in the barley grain during germination the reader would, as already stated, require to be conversant with elementary biology, a branch of science obviously beyond the scope and purpose of the present work.

The changes alluded to should, however, be briefly explained. The skin on the ventral, or in simple language, the semi-oval side of the barley grain, is called the "Paleae superior" and is overlapped on the



R.J.R.-MC.K.

MEDIAN SAGITTAT SECTION THROUGH THE PROXIMAL END OF A GRAIN OF BARLEY

EXPLANATION OF PLATE

p.s.	Superior palea.
p.i.	Inferior palea.
per.	Pericarp.
teg.	Testa.
al.	Aleurone-cells of endosperm.
t.am.exs.	Depleted and compressed cells of endosperm.
t.am.	Starch-containing cells of parenchyma of endosperm.
scut.	Scutellum.
t.abs.	" Absorbtive " and secretory epithelium.
proc.	Elongated parenchymatous cells of scutellum.
ksch.	Plumule-sheath.
$f_1 f_2 f_3 f_4$	Leaves of plumule.
ax_1	Primary axis : ax_2, ax_3, ax_4 ; secondary axis.
pro.	Point of origin of procambium strands.
J.	Growing point of primary radicle.
cal.	Calyptrogen (root-cap).
col.	Coleorhyza (root-sheath).
tph.	Sheath-like cells , remnant of nucellus.
a.x.s.	Basal bristle,
f.p.	Funiculus,

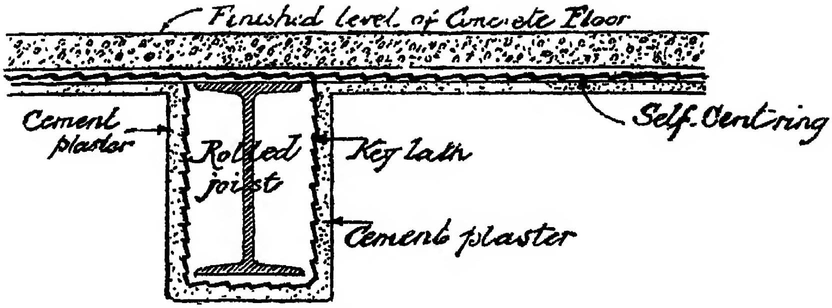
edges of the "Paleae inferior." Beneath the paleae are the two skins, the pericarp and the testa. A great many cereals only have two skins, but in the case of barley the paleae hold closely to the grain and therefore forms a shield to the "acrospire" or sprout, referred to by maltsters as the 'spire or 'spear, which develops beneath the paleae. In huskless seeds such as wheat, the acrospire and plumule (the rudimentary stem or rootlet) grow through the pericarp and testa skins, and thus, unprotected, break off and become spored. This is the difficulty which presents itself in malting wheat, as the acrospire or sprout develop outside the paleae, while the acrospire of barley develop inside the outer covering or skin named.

Immediately inside all the skins there is a double layer of cells containing fat and protein which furnishes nutriment to the young growing plant. These are called the "aleurone" cells. Further still inside the grain there is the embryo (the growing portion) and the endosperm which contains a mass of cells filled with starch granules. The embryo contains virtually all the life functions of the barley.

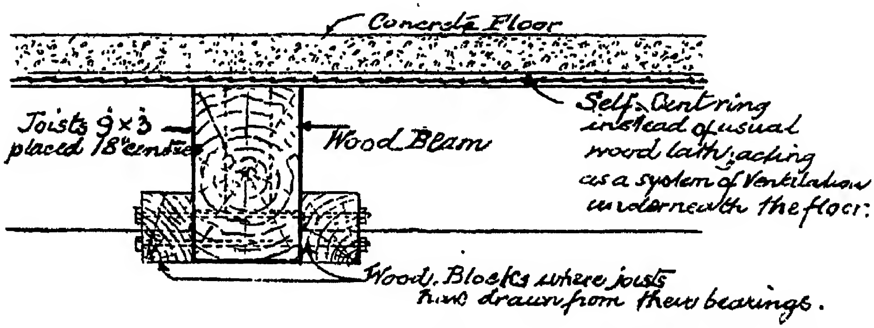
With this necessarily brief description of the constituents of a barley corn the morphological changes which occur on the growing floor of a malthouse should be better understood. It must, however, be particularly noted that these changes are brought about by the action of enzymes, or soluble ferments, which break down or reduce large and complex molecules. The process is termed hydrolyses because enzymic action is always followed by the addition of water or its fixation to the substance upon which the enzyme has acted.

The changes in the barley corn produced by germination on the malting floor are—

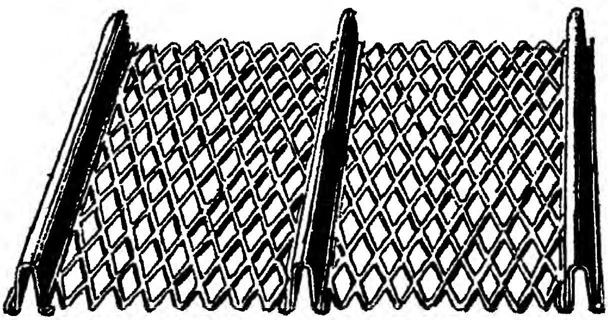
(1) An enzyme termed "Cytase" or "Cellulase" attacks and dissolves the cellulose, or cellulosic tissue, surrounding the starch cells. The cellulose is thus converted into a soluble product and the starch is set



SECTION SHOWING "SELF-CENTRING"
Designed to meet all the various conditions encountered in Brewery and Malting work.



SECTION SPECIALLY DESIGNED FOR RECONSTRUCTING DILAPIDATED CONCRETE GROWING FLOORS IN MALTINGS



PLAN OF EXPANDED METAL FOR SELF-CENTRING TO CONCRETE FLOORS WITH STIFFENING RIBS 13/16 in. IN HEIGHT, PLACED 5½ in. CENTRE TO CENTRE

(J. D. Wood, 3 Newhall Street, Birmingham)

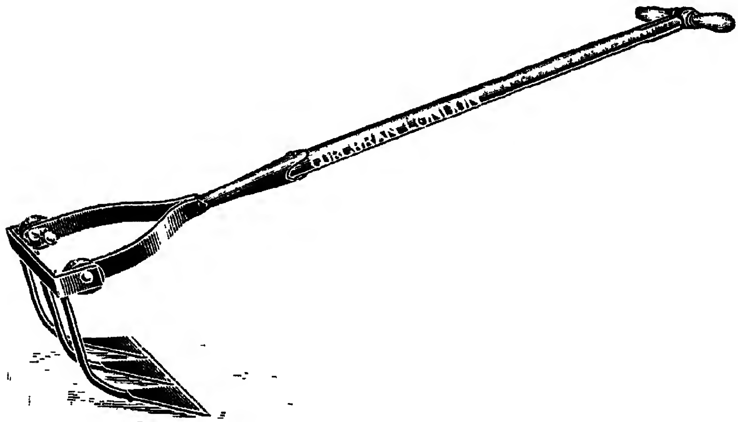
free. The course of the action of the cytase can be followed approximately by a maltster when examining a sample of germinating barley. The extent to which the dissolution of the cellulose has occurred corresponds (unless the germination has been forced by employing high temperatures) approximately with the length of the acrospire. Conjointly with the growth of the rootlets, the maltster aims at developing the acrospire uniformly up three-fourths the length of the barley corn, and this can be readily ascertained by a physical examination of a sample from day to day as germination is proceeding. When the development of the acrospire has reached the desired stage, the first part, or germinating stage, of the flooring process is completed and withering is then commenced upon.

(2) The second morphological change which occurs during malting, and follows the action of diastase, is the secretion in the barley of another enzyme " Diastase" or Amylase." There are two forms of Diastase to be considered, one called " Barley diastase " present in ungerminated barley, the other (to be discussed more fully under the heading of Brewing) secreted in various quantities during germination, the increase in which, with the secretion and promotion of the reducing or dissolving action of the cytase on the cellulose and the development of the rootlets, together constitute the main objects of malting operations.

(3) Two other enzymes have yet to be considered. These are proteolytic enzymes. In other words, they are capable of reducing, or rendering soluble and diffusible, protein (or nitrogenous substances) for the primary purpose of supplying nitrogen in a soluble state to the growing embryo of the barley. The action of these various enzymes will also be described fully when dealing with the initial stages of brewing. The first enzyme is " Peptase " which, at suitable mash-tun temperatures, converts the albumins into albumoses; the second enzyme is " Tryptase," which proceeds a stage further and reduces the albumoses into amides

and amino acids, substances which are readily assimilable as food for the yeast during the fermentation of the wort into beer.

The principal objects of malting, therefore, are the secretion of " Cytase," which subsequently dissolves away cell walls of the starch, the secretion and development of Diastase (the starch reducing enzyme) and Peptase and Tryptase (the protein reducing enzymes) in the correct amounts for brewing purposes. By the

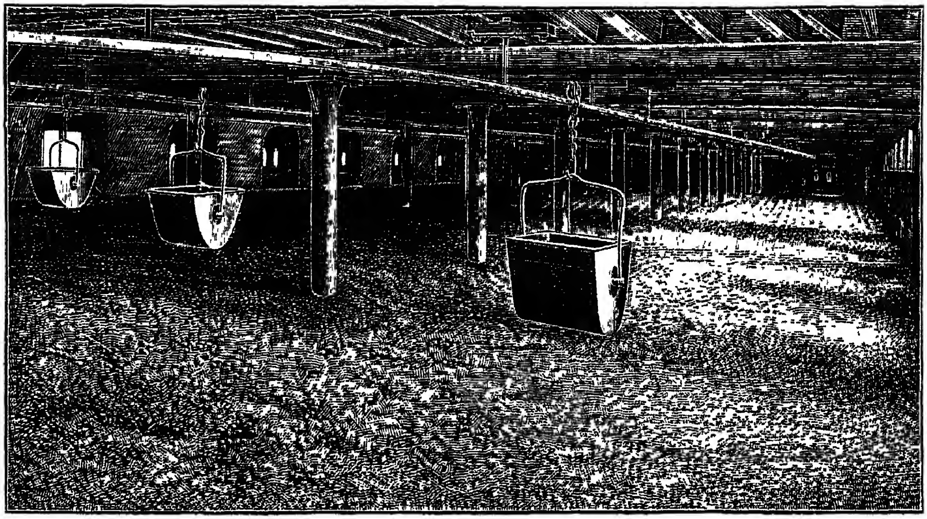


MALT PLOUGH

correct amounts is meant that the maltster must observe that an excess of " soluble uncoagulable albuminoids " is not formed during germination as those substances detract from the stability and brilliancy of the finished beer. To obviate danger from this source the maltster employs low germinating temperatures and avoids excessive sprinkling of water on the " pieces " (separate portions of barley on the malting floor).

The changes which occur in Proteins during the several malting processes are tabulated on page 15.

Barley.		Malt.
Total Proteins 10·6%		*Total Proteins* 9·8%
Composed of—		Composed of—
Insoluble proteins .	8·06%	4·7%
Soluble proteins . .	2·54%	5·1%
	10·60%	9·8%



BARLEY GERMINATING FLOOR WITH OVERHEAD TRAMS

(*Messrs. R. Boby, Ltd. Bury St. Edmunds*)

Sugars Existing in Malt.

Maltose	1·3–5%
Cane Sugar	2·8–6%
Dextrose (Glucose) . . .	1·5–3%
Laevulose	0·7–1·5%

	Ash in Barley.	Ash in Malt.
Potash	15·4%	14·4%
Soda	5·3%	4·9%
Lime	4·5%	5·0%
Magnesia	7·7%	8·3%
Ferric Oxide	0·9%	1·4%
Phosphoric Acid	32·9%	31·2%
Sulphuric Acid	1·5%	1·3%
Silicic	30·6%	32·7%
Chlorine	1·2%	0·8%
	100·0%	100·0%

When the " pieces " exhibit signs of dryness, sprinkling is applied to revivify the germinative powers of the barley.

Ploughing refers to the use of appliances which are drawn through the growing grain with the object of loosening it and reducing the temperature. This is an expedient which does not, except in a minor degree, aerate the barley, and is adopted when considerations of time and labour available do not permit of the more effective method of turning the grain with shovels, thus dissipating the CO_2 formed and permitting the barley to absorb oxygen in its place, which is essential for the promotion of germination. There are occasions and circumstances, as will be noted from the table appended, when ploughing precedes or supplements turning.

CHAPTER III

MALTING ON THE ORIGINAL FLOOR SYSTEM

THE following is a typical table with explanatory notes of correct malting practice on the original floor system, applied to barley of average quality, and deals with the grain from the couching stage—

1st Day. The area of the "pieces" on the several floors of the maltings is arranged in order that the temperature is increased to 56° F. The grain is turned twice (morning and evening) and ploughed in addition if necessary.

2nd Day. Temperature 56° F. The pieces are turned twice and also ploughed again if required.

3rd Day. Temperature 57° F. Turned twice and ploughed in addition if necessary.

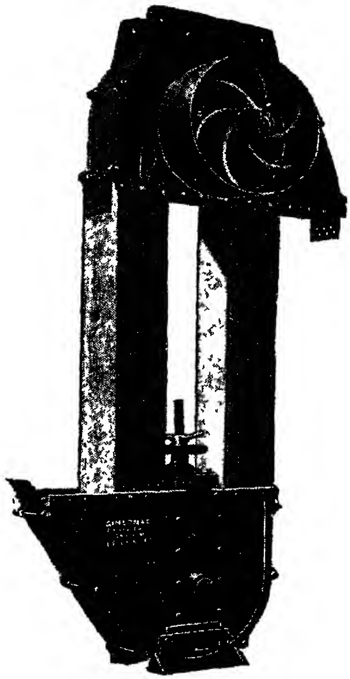
4th Day. Temperature 58° F. Turned in the morning, ploughed at noon, and sprinkled at the rate of half a gallon per quarter of barley in the evening, ploughing and turning after each sprinkling.

5th Day. Temperature 59° F. Sprinkled at the rate of half a gallon per quarter both morning and evening, ploughing and turning after each sprinkling. Ploughed at noon, and again as late as possible that night if this is rendered necessary.

6th Day. Temperature 60° F. Sprinkling at the rate of half a gallon per quarter in the morning and a final distribution of water at the same rate in the evening, only if these "water pieces" require it as indicated by the length of the acrospire and the dry, or, on the other hand, moist condition of the corns. Turn three times at morning, noon and evening, ploughing in addition after each sprinkling, and again at night.

In normal years a total sprinkling liquor amount of two gallons per quarter is sufficient for British barley, but the produce of some seasons is low in germinative

power, and the sprinkling liquor has to be increased to from three to three and a half gallons per quarter. The adoption of longer steeping periods is always preferred to the employment of an excessive quantity of water on the floors which gives irregular germinative



BUCKET ELEVATOR FOR BARLEY OR MALT

(Messrs. Gimson & Co., Ltd., Leicester)

results. In steeping, every corn is wholly covered with water and can thus absorb to its saturation-limit, while in sprinkling the lower layers only of the pieces receive the bulk of the water.

7th Day. Temperature 60° F. Turned morning and evening, ploughed at noon, and again late at night if required.

8th Day. Working procedure similar to previous day. Up to this stage in the malting process the

" turning " is conducted with a view to the dissipation of the carbonic acid gas, CO_2, evolved during germination and the absorption of oxygen by the grain. In other words, the latter is aerated by turning. Opposite conditions of working now prevail throughout the remainder of the malting process. The grain has now reached the withering stage which process is accelerated by the presence and decaying influence of the carbonic acid gas. The procedure of floor working is reversed to restrict the dissipation of the CO_2, which lies in the upper layers and in the interstices between the corns. The ploughing and turning should now be primarily conducted to create the conditions named, and also with a view to prevent balling or matting of the grain and to restrain the natural upward tendency of temperatures.

9*th*, 10*th and* 11*th Days*. Temperature 60° F. to 61° F. Turned morning and evening, and plough late at night if required.

12*th Day*. Temperature 60° F. to 63° F. for British barley, turned in the morning only unless the pieces go beyond the latter temperature named. In the case of foreign barleys a final withering temperature of 65° F. may be employed with advantage.

13*th Day*. Load to the kiln in the early morning when, if the withering process has been correctly carried out, the moisture content at this stage should be 43 per cent.

CHAPTER IV

CONTROL OF KILN WORKING

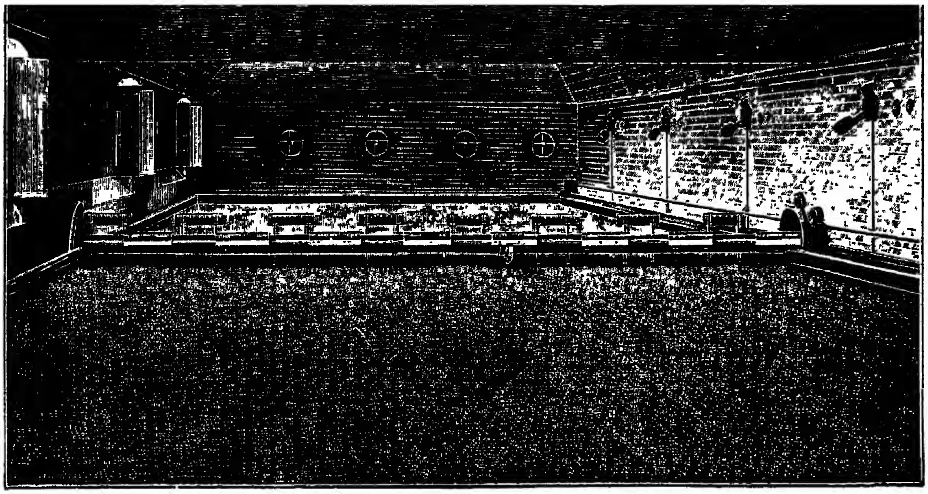
Drying. Care is observed that the withered grain is never loaded over a " green " or freshly kindled fire. Anthracite coal is now alone employed for malt drying and curing purposes, as it contains an almost negligible amount of arsenic. On an average anthracite coal contains about $\frac{1}{400}$ of a grain of arsenic per pound, whereas coke from gas works contains as much as $\frac{1}{17}$ of a grain per pound. With the moisture present in the grain at the loading stage it readily acquires an empyreumatic flavour from the fumes, the original depth of the load should never exceed 10 in., and although high temperatures will dissipate the moisture content of the malt quicker than low temperatures, yet if the load is exposed to initial " heats " of above 100° F. the malt is scorched, and the husk becoming set or fixed imprisons the moisture, preventing its escape from the grain, producing a hardness, or in malting parlance " steeliness" or " flintiness " due to vitrifaction.

The kilning of malt like the floor working consists of two distinct processes. In the former, germination with abundant aeration is followed by withering brought about in a considerable measure by the asphyxiation of the malt. Kilning similarly should be regarded as being divided into two stages—

(1) Drying with an abundance of draught to promote rapid expulsion of the moisture, and

(2) Curing with only sufficient air passing through at high temperatures to maintain the fires, and to obviate the danger of any stagnation of air current through the load on kiln which might result in scorching. This should be controlled more by the louvres on the apex of the kiln than by manipulating the bottom draught holes, which should remain entirely closed throughout

the curing process. If the grain is left long at relatively low temperatures in a moist state immediately after loading, " forcing " occurs and an excess of " soluble uncoagulable albuminoids " is formed which, as already indicated, produce adverse brewing results. Indeed, having regard to the fact that the main object of low floor temperatures is to minimize the production of " ready formed sugars," the amount of which exists



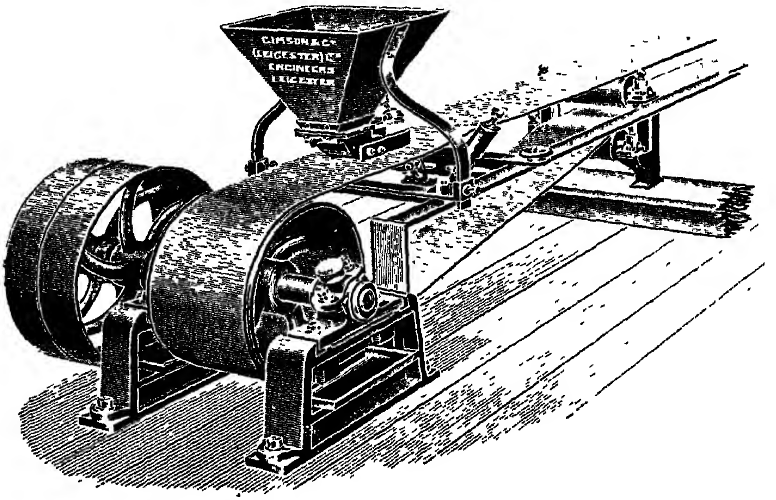
PATENT MECHANICAL MALT-KILN TURNER
(*Messrs. R. Boby, Ltd., Bury St. Edmunds*)

in malt in a fairly well defined ratio to " soluble uncoagulable albuminoids," it will be perceived at once that the precautions covering many days during flooring to prevent the development of the bodies named may be utterly undone on the kiln in the course of a few hours.

What may be regarded as the danger area lies in temperatures between 70° F. and 80° F., to avoid which the initial kiln temperature is raised to 100° F. as soon as practical circumstances permit, but the temperature of the load on kiln is restricted to 100° F. and never

permitted to reach 120° to 125° F. until the grain is "hand-dry," which corresponds approximately to a 10 per cent moisture content.

The draught holes remain open to their full limit to facilitate rapid moisture expulsion. With a sufficiency of draught induced by large fires through correctly placed air-holes low grain temperatures result. The

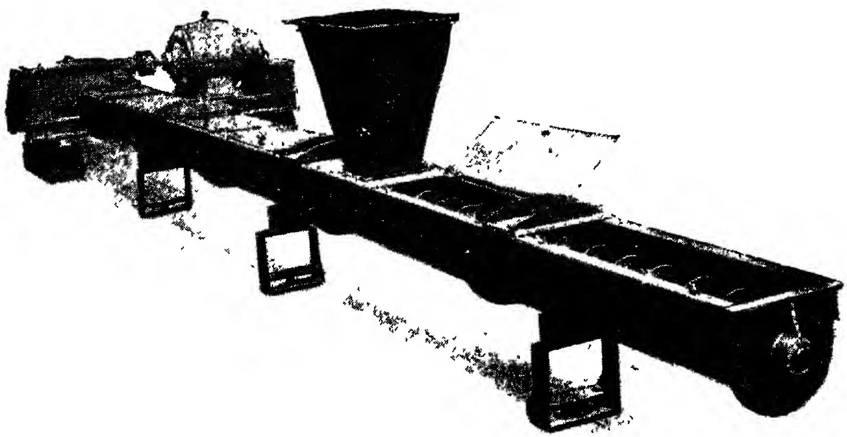


BAND CONVEYOR FOR BARLEY OR MALT
(Messrs. Gimson & Co., Ltd., Leicester)

air supply to the fires is worked independently and has no connection with the draught holes proper. The air consumed by the fires is displaced by further supplies passing through the draught inlets and rushing upwards in such volumes that, when mixed with the fuel gases, the temperature of the entire mass is reduced before it passes through the moist grain.

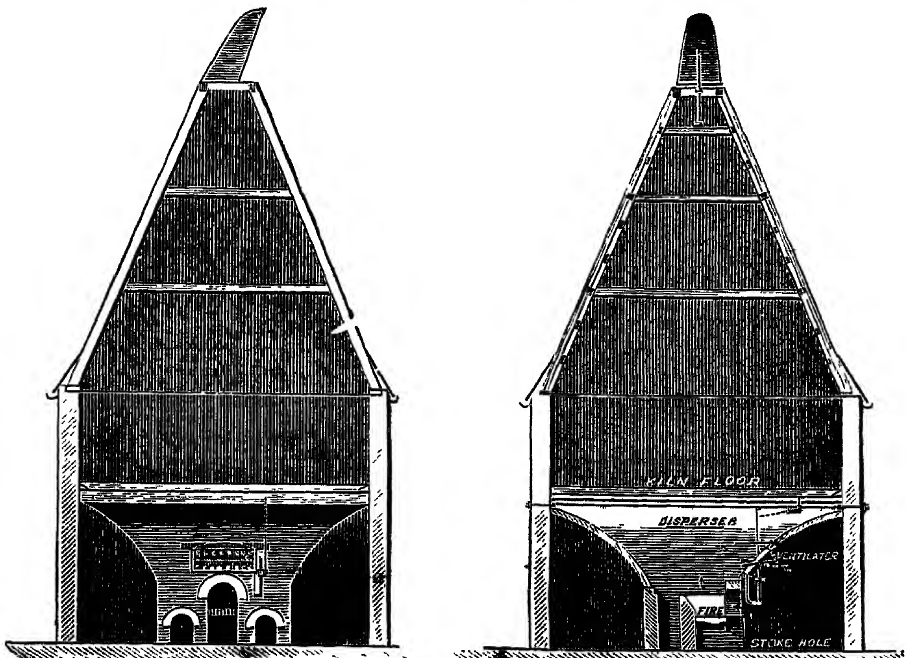
When the construction of a kiln permits of the adoption of this system to the full extent, it is possible to obtain a hard dry malt within forty-eight to fifty hours of loading.

Curing. Directly the load is "hand-dry," the doors of the draught holes are gradually closed and the intensity of the fires gradually lessened with a view to the



WORM CONVEYOR OR ARCHIMEDEAN SCREW FOR CONVEYING BARLEY OR MALT

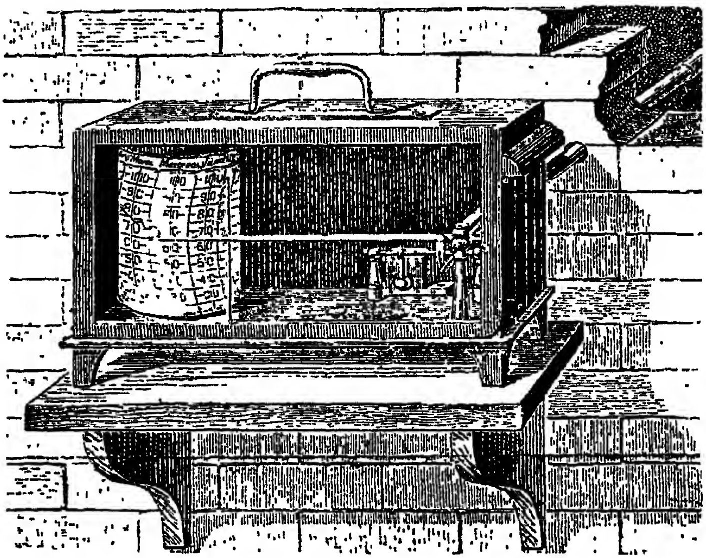
(*Messrs. Gimson & Co., Ltd., Leicester*)



SECTIONAL INTERIOR VIEW OF MODERN MALT KILN FITTED WITH HEAT REGULATOR

(*Messrs. H. J. H. King & Co., Ltd., Nailsworth*)

prevention of too sudden increase in kiln temperature. The object of curing or "firing off" is to reduce the diastatic power; to diminish the moisture present at this stage to the lowest practical limit; and to fix or produce a permanency of general character in the contents of the grain, all of which changes can only be obtained by subjecting the load for some time to high



SELF-REGISTERING, OR CHARTING, KILN THERMOMETER
(Bryan Corcoran, Ltd.)

temperatures. The temperature is raised by degrees to the required maximum by restricting the draught, permitting the heat to accumulate and thus to penetrate the interior of the corns. To obviate the risk of excess colour the drying operation must be correctly performed, when it is then practicable to "fire off" at temperatures of 200° to 220° F. maintained for 10 to 12 hours without affecting the flavour of the finished malt, producing abnormal colour, or unduly restricting diastatic capacity.

During the drying period the grain is forked or lightened at short intervals so long as the load appears

to contain the same moisture percentage throughout. If the forking is continued until the load consists of virtually three layers, varying in water content, then the moist top layer will reverse positions with the lowest and driest layer, the latter thus becoming resaturated with moisture from the former.

During curing, however, frequent forking and turning is advantageous, especially during the last 12 hours or from the 72nd to the 84th hour from loading.

The following tables represent the temperatures employed on an average kiln of standard construction, for various malts—

KILN TEMPERATURES FOR MILD ALE AND PORTER MALTS

	1st Day.	2nd Day.	3rd Day.	4th Day.	5th Day.
	°F.	°F.	°F.	°F.	°F.
[1]M. 2	—	100	110	190	200
M. 6	(Loaded 9 a.m.)	105 (24 hrs. at 9 a.m.)	115 (48 hrs. at 9 a.m.)	205 (72 hrs. at 9 a.m.)	— 185
M. 10	80	105	120	212	—
[1]E. 2	90	105	[2]130	212	—
E. 6	95	110	150	212	—
E. 10	100	110	170	[3]212	—

KILN TEMPERATURES FOR PALE ALE MALTS.

	1st Day.	2nd Day.	3rd Day.	4th Day.	5th Day.
	°F.	°F.	°F.	°F.	°F.
M. 2	—	100	110	185	190
M. 6	(Loaded 9 a.m.)	105 (24 hrs. at 9 a.m.)	115 (48 hrs. at 9 a.m.)	195 (72 hrs. at 9 a m.)	185
M. 10	80	105	120	—	—
E. 2	90	105	130	200	—
E. 6	95	110	150	200	—
E. 10	100	110	165	200	—

[1] Denotes Morning and Evening.
[2] 130° F. Malt hand dry 52 hours from loading, or 2 p.m. on the 3rd day.
[3] 212° F. 85 hours from loading at 10 p.m. on the 4th day.

CHAPTER V

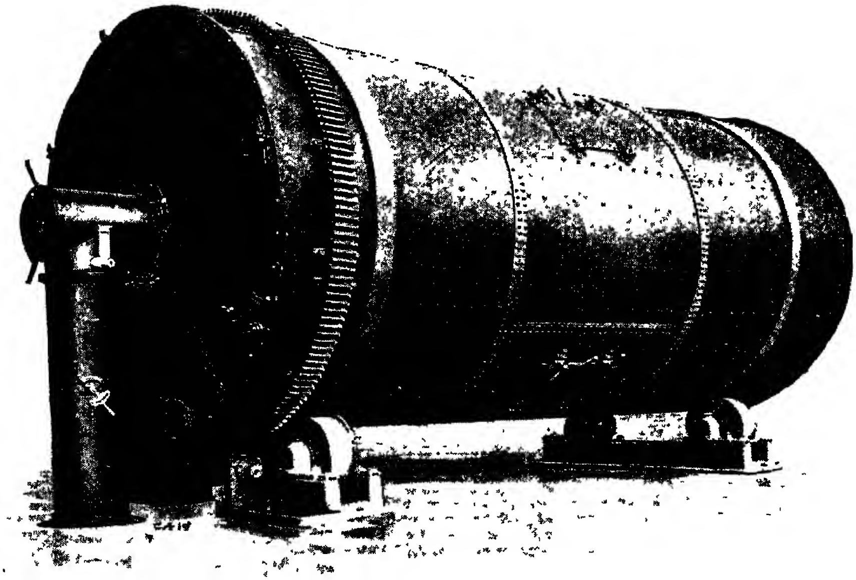
PNEUMATIC DRUM MALTING

THIS has been described as the modern system of malting, to distinguish the manufacture of malt by means of pneumatic drums from the original open floor method of germinating and withering, which has been practised in this country for generations and still predominates. The initial cost of installing the pneumatic system is appreciably higher than the primary expenditure on the floor method, and the latter is maintained and worked more economically. It is not intended here to discuss the advantages claimed for producing malt by the aid of enclosed drums except to touch upon the inherent defects inseparably connected with working on the older systems. In the latter it is impossible to secure absolute control of the temperature on the malting floor. The vagaries of the weather, the frequent alteration of temperature, and the variations in the humidity of the atmosphere render it very difficult for the maltster to maintain the grain at the correct temperature and to ensure a uniform speed of germination.

The maltster obviously cannot forecast climatic conditions, and to accomplish success in any sphere factors which cannot be controlled should be eliminated. Even under the most favourable weather conditions, uniformity of temperature or equable exposure to the influence of oxygen cannot be secured throughout the grain on the same floor, and the barley is necessarily subjected to treatment which precludes uniformity of growth.

The sprinkling process on the original floor method leaves much to be desired. In the hands of the most painstaking workman it is impossible to obtain uniformity in distribution of the sprinkling water—" liquor " is the trade expression. Mould develops in the " pieces "

owing to the damage the grain sustains from the shovels, forks and ploughs employed, and the crushing of loose corns by the maltmen treading upon them. If the weather is moist the mould spreads to such an extent that the malt has to be loaded to kiln before true withering has occurred. In the drum system the temperatures are always under control and the maltster



PNEUMATIC GERMINATING DRUM

can regulate them just as he desires. Mould does not occur as the grain is never trampled upon, it is " turned " mechanically by the drum revolving, and the amount of air admitted to the drums can be either dry or moist as the condition of the germinating barley demands. It is impossible to allow sufficient time at ordinary malting temperatures on the open floor system to thoroughly modify the contents of inferior, unripe, and refractory barleys, whereas in drums the germination and withering may be carried on slowly and for prolonged periods without incurring the risk of mould.

An advantage of employing drums is that they lend

themselves to the CO_2 rest process, where it is claimed the malting loss is reduced considerably when airtight fittings are used. The space required for a pneumatic plant is one-fifth of that rendered necessary for a floor malting. An economical advantage of the pneumatic system is that, being independent of atmospheric influences, it can be operated all the year round, which, moreover, enables the brewer and the maltster to regulate the age and amount of his malt stocks in accordance with trade requirements.

A kiln for both drying and curing is generally employed as on the floor system, though in large installations the ordinary kiln is utilized for drying, completion on of which stage the malt is dropped to a curing drum placed under the kiln floor. By adopting this plan of working a greater output is obtained, due to the fact that when the "hand-dry" malt is transferred to the drum the kiln is set free to receive a fresh charge of green malt.

CHAPTER VI

GERMINATING ON THE PNEUMATIC DRUM SYSTEM

Steeping. This is conducted in conical iron cisterns, the temperature of the contents at various depths being ascertained by thermometers fixed for the purpose; and in cold weather the temperature is regulated by operating a steam jet. In some cisterns the barley is washed during steeping and aeration carried on while renewing the steep water.

When the steeping process is completed the grain is transferred to the drums, which are revolving cylinders provided at one end with a circular air space from which perforated horseshoe pipes are carried the length of the drum at intervals of two feet. Through these pipes the air enters the drum and after passing through the grain is carried out by a large perforated centre tube. One air shaft serves the entire installation of drums, and the air, the volume of which is completely under control, is drawn through a moistening tower and thence conveyed by fans to any or all of the malting cylinders.

The drums are of 30 to 40 quarters capacity, and rest upon wheels which are slowly rotated, each revolution occupying from 30 to 40 minutes. The surface of the grain is continuously maintained at an angle of 20°, and as turning proceeds the corns slide over without damage to the delicate rootlet. Each drum has an aperture closed by a cover through which the steeped grain is introduced, and in each there is also an apparatus for sprinkling the grain. The supply of air, the number of drum rotations, temperature of grain, and time and quantity of sprinkling liquor depend on the type and condition of the barley undergoing germination. There are no established rules of procedure to follow, but usually when the barley is dropped from the steep

the drum is rotated once without aeration. As in floor working, the temperature of the barley is controlled by the speed and uniformity of germination. As the latter proceeds and reaches completion it is followed by the withering process, which takes place in the same cylinder and is carried out on precisely the same principles as on the original floor system but more efficiently, and that by completely cutting off the air supply to the drums the green malt is asphyxiated and true withering readily occurs. The malt is then discharged from the cylinder to the kiln where the concluding operations are carried out in the manner already described.

CHAPTER VII

TYPICAL WORKING METHODS ON THE PNEUMATIC DRUM SYSTEM DURING A TWELVE DAYS GERMINATING AND WITHERING PERIOD

1st Day. The barley being placed in the drum the latter is rotated once or twice, and a full current of air passed through to ensure that the entire contents of the drum may be aerated and moistened uniformly. For the remainder of the day the drum remains stationary with the air supply cut off and the grain temperature maintained at 56° F.

2nd Day. The drum rests for the main portion of the second day, with rotations of one hour at intervals of from 6 to 8 hours. While the drum is slowly revolving a small volume of air may be passed through the grain.

3rd Day. At this stage germination should have commenced and the drum should be rotated freely, but with only as much aeration as the condition of the grain renders necessary. As a general rule the drum is rotated every 2 hours, each revolution occupying 45 minutes, and the temperature of the "piece" is maintained at 58° F.

4th Day. Sprinkling is commenced. As the drums rotate slowly the doors are opened and water is distributed over the barley by neans of a fine sprinkler. Care is observed that the air supply is cut off while sprinkling is proceeding, otherwise the bulk of the water added will be drawn off by the current. To ensure a thorough intermixture of the sprinkling liquor with the grain, the cylinder is rotated freely directly after the requisite volume of water has been added. The same method of dividing up the total sprinkling liquor into separate portions and distributing them at intervals is adopted when employing cylinders as on the floor system. Similarly the volume of sprinkling liquor is controlled

by the progress made in the development of the acrospire. In the original system, however, as already explained, three-quarters "up" the length of the grain is customary, whereas with drums the acrospire is allowed to run up to seven-eighths.

6th Day. The drum is revolved every alternate hour and the temperature maintained at 60° F. The final sprinkling is given on this day and the quantity varies from 1½ to 2 gal. per qr. The same volume is added through each door and the rate is readily controlled by noting the time occupied in sprinkling by means of a watch. The total quantity of water employed for sprinkling amounts to 6 gal. per qr. steeped.

7th Day. Rotate the drum every two hours for a period of one hour.

8th and 9th Days. As above.

10th Day. As on the previous three days. In the afternoon the supply of moist air from the cooling tower is shut off, and dry air from the malting room is admitted to the drums for the purpose of drying the surface of the load.

11th Day. Withering is commenced by completely shutting off the air from the malt, thus allowing the accumulated carbonic acid to exercise its full withering effect on the green malt. The malt is at this stage allowed to gradually increase in temperature. An undue increase in temperature is controlled by rotating the drum and, if necessary, a small volume of cold air is admitted.

12th Day. Similar to 11th. The temperature may have now reached 70° F., and the malt is then ready for loading to the kiln.

CHAPTER VIII

THE THEORETICAL LOSS IN MALTING

THE mean natural weight of a bushel of "malting quality" British grown barley is 56 lb., or 448 lb. per imperial quarter of 8 bushels. The average natural weight of a bushel of foreign grown barley suitable for malting purposes may be regarded as weighing 50 lb., or 400 lb. per imperial quarter. Maltsters invariably purchase both home and foreign produce weighed up to 448 lb. per quarter, although under a recent Act barley should be sold and purchased in terms of cwts.

Malt, if correctly manufactured from British grown barley, weighs 42 lb. per bushel, or 336 lb. per quarter. Hence it is that the theoretical loss in malting is 25 per cent. This loss may be expressed as due to—

Rootlets	4%
Respiration	4%
Steep	2%
Moisture	15%
	25%

But it should be noted that these figures apply to correctly malted samples. It seldom occurs, however, that every corn germinates if the barley is home grown. Ungerminated grain is referred to as "liebacks" or "idlers," and barley harvested in wet seasons contains a heavy percentage of these dead corns, and in addition a higher moisture percentage than 15. Theoretically, therefore, if a maltster steeps 100 qrs. of barley weighed up at purchase to 448 lb. per qr., he should obtain 100 qrs. of malt at 336 lb. per qr. The percentage of ungerminated corns in various consignments of British barley malted in the course of a season may reach 5 per cent, and is in few instances less than 3 per cent.

Foreign barley of malting quality on the other hand usually germinates in the words of the maltster "to a corn," and there is virtually no increase on the heading of idlers, but foreign grain unfortunately invariably reaches the malthouse containing a large percentage of light husky material and heavy extraneous matter, which taken together form a high ratio of screenings, and if the consignment is bought unscreened it reduces the malting increase proportionately. The moisture percentage of foreign malting barley may be taken as 10 per cent in comparison with the average water content of British grown of 15 per cent; a consignment of efficiently screened foreign barley purchased at 448 lb. per qr. should therefore yield a quantity of correctly made malt at 336 lb. per qr. from 6 to 9 per cent in excess of the original weight of barley steeped, or, as this increase is termed, "outcast."

The following is another method of ascertaining the loss which occurs in the malting process—

2,000 barley corns weigh 81·32 grains.
2,000 malt corns weigh 67·04 grains.

$$\therefore \frac{67{\cdot}04 \times 100}{81{\cdot}32} = 82{\cdot}4\% \text{ of malt.}$$

$$100 - 82{\cdot}4 = 17{\cdot}6\% \text{ loss on barley.}$$

Loss in	Steeping	1%
,,	Rootlets	3%
,,	Water	10·3%
,,	Respiration	3·3%
		17·6%

Quarter of barley	448 lb. =	barley 100.
Standard Quarter of Malt	336 lb. =	malt 75.

75 is reckoned the standard for malting—

$$\frac{100 \times 82{\cdot}4}{75} = 109{\cdot}87\%$$

Less	100·0%
"Outcast" (or Increase)	9·87%

Correctly withered malt should when loaded to kiln have a moisture content of 43 per cent. On completion of kiln drying this is reduced to 10 per cent and finally to 1 per cent with curing; when the finished malt is transferred to air-tight bins at the termination of a storing period of at least a month the malt is sufficiently matured for use in the production of beer or stout.

While the quality of the finished malt depends, of course, on that of the class of barley employed, yet a skilled maltster can produce a good malt from medium class grain of sound germinative capacity, and an unskilled or inexperienced craftsman fails to manufacture a good malt from the highest standard barley obtainable, purchased probably at a fancy price. The complete valuation of malt comprises a physical examination taken in conjunction with a correct interpretation of the results of a chemical analysis, which is dealt with fully under the heading of Laboratory.

PART II
BREWING

PART II

CHAPTER I

BREWING

BASED on the epoch making and classical discoveries of Pasteur on beer and alcoholic fermentation, published in 1857, international scientists have since found in a close study of the preparation of beer a source of knowledge opening up a vast field to further research, the results of which have been applied to the combating of disease and the alleviation of pain, thus proving of incalculable value to mankind.

WATER

The subject of water, although a very important one in connection with brewing, does not now occupy that position of especial significance which it once held, either technically or from the point of view of the general public. That a water utilized for brewing purposes must be in an eminent degree organically pure and free from objectionable metals and minerals is an indispensable condition. Water containing other than a trace of free and saline ammonia and albuminoid ammonia, nitrates, nitrites, and oxygen absorbed, indicate pollution or an excess of organic matter which renders the water unfit or unsuitable for brewing purposes. But the fact that a water may be wholly lacking in minerals does not preclude its successful employment. Indeed, the modern brewer prefers a water of this type to one containing salts (1) that are not required, (2) are necessary but not in the amount present, or (3) the presence of which is disadvantageous. Water will

always remain the principal constituent of malt liquors, and the brewer concerns himself in becoming conversant with the influences—favourable and adverse—exerted by the various salts upon the materials employed, upon the yeast and fermentation, and subsequently as to the manner the saline contents of a water affect the general qualities of the finished beers.

The malt beverages of well-known districts owe their original popularity to the type of water obtainable there, but this reputation for excellence of manufacture was gained, it should be noted, prior to 1879, in which year E. R. Southby, a Burton brewer and chemist, commenced his epoch-making investigations on water ; researches since continued by the leading brewing chemists and technologists of the world.

Whether a water is naturally suitable for brewing purposes or rendered so artifically by the addition of the requisite salts, the results are technically identical.

The following is a typical example of a Burton deep well water, showing how the bases and acids present are regarded as existing in combination—

	Grains per gallon.
Sodium Chloride (Common Salt) . . .	3·90
Potassium Sulphate	1·59
Sodium Nitrate	1·97
Sodium Sulphate	10·21
Calcium Sulphate (Gypsum or Sulphate of Lime)	77·87
Calcium Carbonate (Carbonate of Lime) .	7·62
Magnesium Carbonate	21·31
Silica and Alumina	0·98

In the opinion of Southby, already alluded to as the pioneer of original research upon the subject, nearly all deep well waters contain nitrogen in the oxidized form of nitrates or nitrites. The former is formed by nitric acid combining with a base, and if their presence be due to pollution by animal matter, the brewer's yeast is eventually weakened, faulty fermentations result, which inevitably affect the brilliancy, flavour, and stability of the finished beer. The more dangerous

nitrites, formed by nitrous acid, if derived from matter of animal origin, and if present in excess of one or two degrees the water is regarded as useless for successful brewing. Further, nitrates and nitrites, especially the latter, lead to trouble with the beer in cask by "fretting," a term applied by brewers to beer that generates excessive condition. No amount of mechanical filtration or manipulation will convert a heavily nitrated or slightly nitrited water into one that can be employed for brewing purposes throughout the year.

Unfortunately many well waters while containing useful salts possess others in a permanent form which are objectionable. In some instances it is possible to diminish if not to eliminate these useless or injurious features by decomposing them, referred to as "double decomposition." This means the addition of acids or a further number of minerals for the purpose of converting those not desired into others which may serve a better purpose in the general scheme of brewing water manipulations. Brewers, however, are averse to employing brewing water which necessitates the treatment mentioned, as there is always the disturbing element of uncertainty present when such a process is adopted on a large scale in a brewery. There are two expressions often used when describing the mineral constituents of water, i.e. "temporary hardness" and "permanent hardness." Carbonates are precipitated on boiling the water, therefore the so-called "hardness" conferred by carbonates is of a temporary nature. Boiling has no effect on the solubility of sulphates, which therefore confer a hardness of a permanent character on the water. It is not to be wondered at, then, that many brewers prefer a soft water in the sense that it is wholly free from mineral matters in solution. Brewers can, and do, successfully employ surface catch-water or a town supply, which, with the care bestowed upon it now with regard to filtering and periodic chemical analysis and bacteriological examination, can be relied upon as being of undoubted purity and free from sewage

contamination, temporary hardness and objectionable salts, and with this at his disposal a brewer can manipulate the water by the addition of the requisite mineral matter for the production of mild beers, pale ales and stouts. As will be explained when considering the properties of the various salts, each perform a definite function in brewing different types of produce, and it is clear that the brewery with a soft catch water pure organically and in other respects, or a municipal supply, is in a much better position than the establishment where the only available supply is of a permanently hard character, with which it is impossible to produce mild beers, bitter ales and stout with equal success and, except in isolated instances, the modern brewery must be in a position to offer for sale all the three types of beverages named.

The essential salts may now be considered *seriatim*.

1. Gypsum (Sulphate of Lime $Ca\ SO_4$)—Of all the minerals required gypsum is the one employed largest in amount. Although sulphate of lime does not lessen the quantity of protein dissolved from malt the salt possesses the property of coagulating, or separating out in the form of flakes, certain classes of nitrogenous matter present in malt wort. In other words, gypsum is the principal factor responsible for the "break" which occurs when brewers' wort (or infusion of malt) is boiled. The term named is applied to a countless number of minute particles which can be observed in suspension in a sample of boiled wort. These flakes are readily filtered off with the spent hops, as will be better understood from the description given later of the various brewing processes. In the absence of gypsum the dissolved proteins remain in a finely divided form in which state of semi-solution much of this coagulated matter resists filtration and precipitation, and is thus carried forward to the cask, affecting the brilliancy and stability of the finished beer. The presence of gypsum prevents the over extraction of the rank bittering qualities of the hops, which accounts, together with the

removal of the coagulable proteins, for the clean and dry delicate flavour conferred on beers brewed with the correct proportion of sulphate of lime in the brewing water. An excess of gypsum beyond that necessary to ensure the essential "break" in the malt is to be deprecated both on commercial and technical grounds. On the principle that there is safety in excess, some brewers employ an excess of gypsum with the result that the action of the enzymes is crippled and the malt reaches the fermenting vessel deficient in yeast food with an abnormal proportion of high type malto-dextrins, or saccharine substances which, for reasons explained later, are not readily fermentable. In point of fact an excess of gypsum has to some extent the same effect on the finished beer as the use of over-cured malt, malt of very low diastatic capacity, or too high a "striking temperature," the expression applied by brewers to the temperature of the water employed for mashing, or the admixture of water and ground malt—the initial process of actual brewing. In pre-war days, with beers of comparatively heavy original gravity, gypsum was used at rates ranging from 50 to 70 grains per gal. of water. With the restriction in beer strengths due to an extortionate fiscal duty, high prices for materials and labour, and the control of average gravity, high saline rates are not only unnecessary but are disadvantageous commercially.

With regard to the preparation of water for brewing purposes, natural sulphate of lime which can be purchased at a cheap rate and is obtained from the rock and ground to a powder is not recommended, as despite all precautions to ensure solution a considerable proportion of the natural salt will not dissolve. More uniform results are obtained from the adoption of the synthetically prepared substance, i.e. sulphate of lime made by the addition to boiling water of sulphuric acid and calcic carbonate. The latter neutralizes the former and, when the water is cooled, the sulphate of lime which has been formed is precipitated and can if need be

recovered when the liquid is run off. Gypsum is not required in the brewing of stout or porter.

(2) Sulphate of Magnesia ($Mg\ S\ O\ 4$)—This mineral is always used in conjunction with gypsum. The part played by sulphate of magnesia is not definitely known, although it is generally agreed that it functions in the vegetable and animal economy in a similar manner. Only a small quantity of the salt is required, from 4 to 6 grains per gal. being sufficient. The mineral constituents of yeast as found in the ash include sulphate of magnesia, so that it also serves as a mineral food for the yeast. An all-malt wort it is true yields the entire mineral requirements of a yeast, but with the modern practice of using high proportions of malt adjuncts containing little or no inorganic nutrient, brewers find it advantageous when producing ales to add a few grains of sulphate of magnesia together, of course, with other nutrients as contributory factors in maintaining the yeast in a healthy and vigorous condition. The material composition of stout and porter, being derived mainly from native grown malt—on account of the full flavour which is essential to this class of produce—contains the requisite mineral food, and sulphate of magnesia is dispensed with. Further, a large proportion of these so-called "black beers" reach the consumer in a fresh condition, and as they in addition contain rather more unattenuated or unfermented sugars than ales, the use of sulphate of magnesia is avoided.

(3) Chloride of Sodium, Common Salt ($Na\ Cl$) and Chloride of Calcium ($Ca\ Cl\ 2$).

These are the only chlorides used in brewing in the treatment of water for the production of any type of malt produce. As sulphates impart a dryness to the finished beers, chlorides confer a decided and much desired full round flavour. This is due to the fact that chlorides are powerful solvents and dissolve out more of the proteins from malt. They also increase enzymic action, thus furnishing additional supplies of readily

assimilated nitrogenous matter available as yeast food, and the type of malto-dextrins (malt sugars) is a low one. It is obvious therefore that chlorides accelerate the speed of fermentation, and that the finished beer is appreciably mild and full flavoured and will come into condition readily. Chlorides also increase the stability of every class of malt beverage. Chloride of calcium is used to the extent of 10 grains per gal. in the brewing water for bitter ales, while chloride of sodium (common salt) can be added with advantage in the manufacture of mild ales and stouts to the arbitrary limit of 30 grains per gal.

(4) Kainit—This natural substance obtained from Italian mines and sold in a purified state was formerly employed by brewers, but its use has almost wholly been discontinued mainly owing to its irregularity of composition. The material contains a large percentage of the sulphates and also the chlorides of the alkalies potash and soda, mineral constituents of yeast, and it is this factor which originally attracted brewers to the use of Kainit.

We have dealt in the foregoing pages with the successful treatment of soft waters in general. Exceptional types of water exist which, for many reasons unnecessary to discuss here, no amount of manipulation or filtration can render satisfactory for brewing purposes. But these supplies are rare examples, and their existence does not alter the fact that, in the majority of instances, soft waters can be treated which will enable them to be employed with success in the manufacture of any class of beer desired. Double decomposition has already been referred to and, although theoretically correct, when carried out practically on a large scale in a brewery the results are disappointing, except in the case of boiler treatment, when the prevention of incrustation is in the main the principal question to be considered.

To calculate the weight of salts required for a brewing, the following method is adopted. Assuming that the total quantity of water required, after making due provision for wastage in boiling, cooling and absorption

by the materials of the brew, is 125 barrels (each of 36 gals.). If the brewing liquor is a soft supply free from mineral matter then the calculation is simplified, whereas, if there are some grains of permanent hardness of the salts required naturally present, then due allowance should be made for them. It is decided, we will further assume, to "harden" the 125 barrels to the arbitrary standard of 50 grains of gypsum, six grains of sulphate of magnesia and 10 grains of chloride of calcium—

125 barrels $\times$ 36 = 4,500 gals. $\times$ 50 = 225,000 total grains of gypsum required. As there are 7,000 grains in one pound $\therefore \frac{225,000}{7,000} = 32{\cdot}1$ lb. to which 20 per cent must be added for water of crystallization.

$\therefore (32{\cdot}1 \times {\cdot}20) + 32{\cdot}1 = 38\frac{1}{2}$ lb. of anhydrous gypsum. The sulphate of magnesia required can be ascertained in the same manner—

$$\frac{4{,}500 \text{ gals.} \times 6 \text{ grains}}{7{,}000} = 3{\cdot}85 \text{ lb.}$$

To this amount we add 50 per cent for water of crystallization.

$\therefore (3{\cdot}85 \times {\cdot}50)\ 3{\cdot}85 = 5\frac{3}{4}$ lb. of anhydrous sulphate of magnesia.

Owing to its property of deliquescing, or power of absorbing moisture with avidity, calcium chloride is sometimes supplied as a liquid, and this is usually in a saturated solution form the specific gravity of which is 1380, and the addition of $\frac{1}{20}$th of a pint per barrel represents 10 grains per gal.

$$\therefore \frac{125}{20} = 6\frac{1}{2} \text{ pints of calcium chloride.}$$

Calcium chloride is now obtainable in the form of *specially* prepared flakes which are not so readily deliquescent as the salt ordinarily supplied in granular and powder form. To calculate the amount of calcium chloride necessary when dealing with flakes we proceed as follows for the above brewing—

$$\frac{4{,}500 \text{ gallons} \times 10 \text{ grains}}{7.000} = 6{\cdot}42 \text{ lb.}$$

To this amount we add 70 per cent for water of crystallization.

∴ (6·42 lb. × ·70) ∴ 10·91 lb. of anhydrous chloride of calcium.

The method generally advocated for water manipulation is to add whatever salts the water is deficient in to the "hot liquor back," the vessel that supplies the brewing water, but gypsum which (in amount) is the principal salt to be considered is not more soluble in hot water than in cold, and the added sulphate of lime being virtually in suspension has a tendency to subside and produce irregularity of results in respect to the saline content of the finished beers. Uniformity in the latter regard is best secured when the whole of the powdered "hardening" substances is added while the grist, or crushed malts, are running in to the grist case. By this means the sulphates and chloride of sodium—if the latter is employed—are mashed together with the grist, and they act upon the malt constituents at the very period when the enzymes or reducing agents are at their maximum activity.

When chloride of calcium is used as a fluid it can be allowed to flow into the mash-tun with the grist at mashing, but if flakes are employed then they can be added to the grist together with the other dry salts.

Hydrogen Ion Concentration

Dr. A. L. Stern, in the *Dictionary of Applied Chemistry* (1922), says: "On the whole the evidence indicates that although the nature of the dissolved salts has some effect, yet the chief results are due to the change which the salts produce on the hydrogen ion concentration when the malt is mashed with the water. The effect of acidity on enzyme action is well known, and the bad effects of alkaline waters are largely due to their restrictive effect on enzymic action."

CHAPTER II

MALT ADJUNCTS AND THE PURITY OF MODERN BEER

In response to the clamouring of agriculturists, Mr. Gladstone repealed the malt tax in 1880, since when a fiscal duty has been levied on the original gravity and quantity of beer brewed. The transference of the tax from the malthouse to the brewery coincided with the introduction of more scientific methods of manufacture in both departments, as it conferred a freedom upon the brewer which he had not hitherto enjoyed, by allowing him to employ whatever materials he considered most suitable for the beer desired in his particular district, to which indulgence is due the creation of the now somewhat hackneyed phrase, the "free mash-tun." So unexpected were the results from the abolition of the malt tax that the farmers' hopes of securing a higher price for their barley, from a presumed increased demand, failed to be realized, and a new party was soon formed bearing upon its banner the words "Pure Beer." Sir Cuthbert Quilter brought forward his Pure Beer Bill so frequently in the House of Commons until his death in 1911 that the bill was latterly dubbed "Quilter's Annual." In the following year a new society was constituted under the title of the "Pure Beer League" for the purpose of creating public opinion in favour of "Pure Beer," defined by the society as beer made from malt and hops only. Farmers and others similarly interested in the production of barley have therefore contended for the past 46 years that brewing materials other than malt and hops are "mere substitutes for the genuine article," and by adopting this obviously hypocritical attitude on the question of beer purity they are actuated solely by reasons of self interest. This cry for so-called "pure beer" has not been taken up for the purpose of obtaining, as they would have us believe, an improvement in the

drink of the people, but with the idea that if brewers lost their freedom of choice in materials the demand for British grown barleys would increase and prices in consequence would appreciate enormously. Brewers have been also assailed with employing adjuncts wholly with a view to lowering the cost of producing the beer they require. It is not considerations of economy that compel brewers to use foreign barley malts and adjuncts, but as stated in the evidence given before the Pure Materials Committee (1899), it is due to British malts of even the highest class containing an excess of immature substances, mainly of a nitrogenous character, that require diluting by employing materials which are in themselves purer and more free from crude matters in order to produce the brilliant and wholesome beers now to be found throughout the length and breadth of the land. In point of fact both foreign malt, and especially sugar—the latter being the principal adjunct used—are considerably more expensive, calculating the cost on extract yield, than malt, and yet cane sugar as an essential ingredient in modern beers enters in some proportion into the material composition of every brewing. The only other adjuncts employed are maize and rice, both of which cereals as prepared for beer production yield matters in solution chemically purer than the soluble extracts obtained from either barley malt or sugars.

It is interesting in this connection to compare the present purity of Honest British Beer with the so-called "malt and hops" concoctions of former generations. Among the vile substances which could not fail to affect public health adversely, utilized in the days of empiricism in an endeavour to promote stability and create certain flavours in the beers of that period, were the following: Grains of paradise; powdered eggshells and crab-claws; salts of tartar; seeds of wormwood; wild carrot seed; horehound juice; quassia; daucus seeds; ginger; powdered oyster shells; hartshorn; coculus berry; coriander seeds; powdered nutmeg; aniseed; cloves;

broom ; century tanzy ; sage ; cardius and others equally unsavoury.

Modern brewing methods are under the strict control of the Customs and Excise officials, who under statutory powers are furnished with the means of entry to brewery premises at any hour of the day and night. Not only must regular and definite declarations be made in respect to every material used in brewing, but the wort and finished beer are continuously being subjected to chemical analysis at the Government laboratory.

In striking contrast to the above list of bodies of extraordinary character and dubious origin, the remarkably high standard of general purity attained by present day brewers in the manufacture of the national beverage is exemplified by the exhaustive report published from time to time by the State Analyst of the results obtained from the analytical examination of thousands of samples of brewing materials, of wort, and of beer drawn from various sources.

What then are the adjuncts now employed in brewing and what purpose do they fulfil ? All of them are virtually free from nitrogen and thus function as diluents of the crude protein present in all malt worts. Adjuncts therefore accelerate true condition and maturation, assist clarification, ensure brilliancy and confer a characteristic flavour and one moreover demanded by the public ; a combination of factors favourable to the use of adjuncts which brewers cannot afford to ignore.

Invert Sugar. Of natural sugars, cane alone is used ; but as it is not directly fermentable it must be inverted before it can undergo fermentation. Inversion can be produced by the enzyme *invertase or invertin* present in yeast, and through the mediation of acids. Invert sugar is sometimes manufactured through the agency of yeast at temperatures above those which bring about vinous fermentation, and this particular method is known as Tompson's Process, but the acid process is chiefly adopted. By this method dissolved cane sugar in the presence of a small volume of sulphuric acid

is converted into "invert," after which the acid is neutralized with whiting. The resultant sulphate of lime is allowed to subside, and the supernatant syrup is filtered through beds of charcoal and thus purifies the liquid "invert"; if made from correct material it will eventually settle or "set" into a semi-solid consistency. "Invert" consists of two sugars, Dextrose and Laevulose, in equal proportions. The former is readily fermentable in the brewers' vessels, but Laevulose does not undergo fermentation with the same ease, and the greater portion of this sugar is carried forward with the finished beer to the cask, where it is slowly reduced to alcohol and carbonic acid gas. Hence the partiality of brewers for "invert" which, derived from the cane sugar, is itself free from matters that affect brilliancy and thus acts as a diluent of crude protein in malt worts; while invert at the same time supplies a distinctive flavour and maintains the beer in condition while on draught. Although in some instances brewers prepare their own invert either by the yeast or acid process, in the vast majority of cases invert is purchased from brewers' sugar refiners, who are in a better position to adopt effective refining measures and to specialize in its preparation.

Caramel. This is employed for colouring beers, and it serves the double purpose of colouring and flavouring porters and stout. It can be manufactured from glucose and other saccharine substances, but should, where flavour has to be considered, be prepared from cane sugar. Considerable skill and long experience is required in effecting caramelization successfully, without producing an objectionable burnt flavour and converting the original material into a mere residue of carbon. Extremely high temperatures must of necessity be employed and these obviously involve great care in control. A correctly manufactured caramel should yield a permanent colour of virtually entire solubility, and free from harsh, acrid, or metallic flavours; apart from the disadvantage of an objectionable aroma

imparted by an inferior caramel, an imperfectly manufactured material will yield a solution that may develop a haze in the beer or lack permanency of tintorial power, a loss of colour ensuing from this source during storage.

Black and Coloured Malts. The first named is used solely for colouring and conferring a distinctive flavour on porter and stouts. Black malt is germinated barley which is subsequently roasted in a cylinder revolved over an open fire. Ungerminated roasted barley is also used as a colourant and flavouring medium, but the extract from the raw cereal is naturally crude and the flavour harsh and dry, as compared with the smoother and more palatable flavours obtained from malted barley roasted with care. Coloured malts include chocolate, brown, etc., amber and crystal malts, all of comparatively low tintorial capacity but distinguished for the high measure of characteristic "malty" flavour which the extract from these adjuncts confers upon mild beers, porter and stouts. Coloured malts are not roasted as in the case of black or so-called "patent" malts, but obtain their flavour and colour as the result of, in the main, employing inordinately high temperatures in the presence of excess moisture on the kiln.

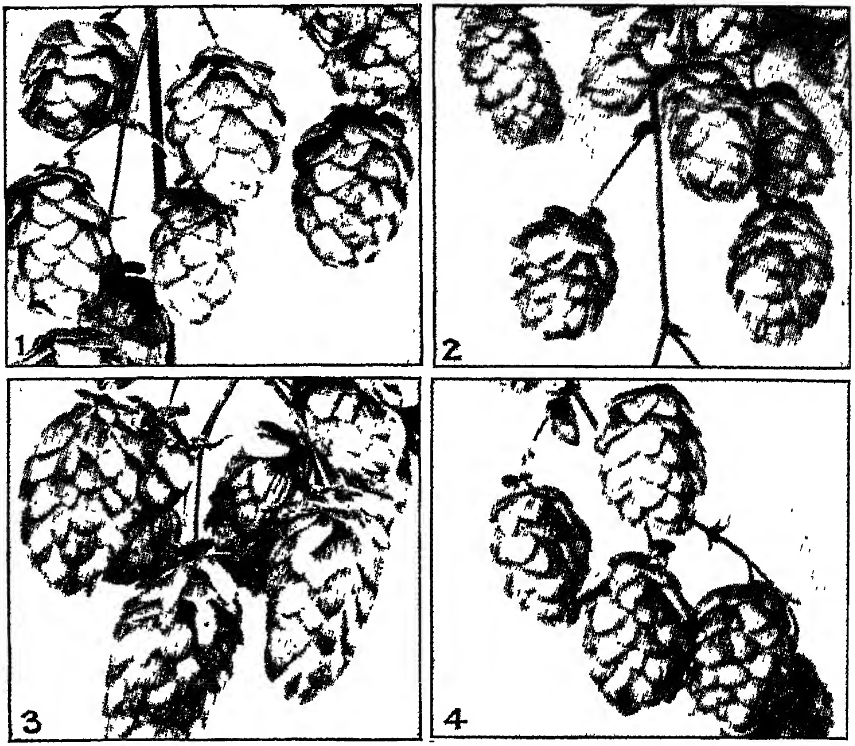
Prepared Malt Extract. As a brewing auxiliary malt extract prepared with a diastatic power of approximately 100° is now used extensively by progressive brewers. Briefly its main functions are—(1) Furnishes *in itself* all the elements of yeast nutrition, organic and inorganic. (2) Contains proteolytic enzymes, and the liquefying and saccharifying diastases, all of which act, if the malt extract syrup is correctly applied, on the unmodified portions of the barley-grain ("hard-ends"). The employment of prepared malt extract syrup improves the general character of the finished beer by (*a*) conferring an additional roundness and fullness on the palate, (*b*) enhanced "malty" flavour, (*c*) augmented stability, (*d*) freedom from yeast-bite or yeastiness, faults especially prevalent in low gravity mild beers, and (*e*) a close tenacious "head" or foam.

CHAPTER III

HOPS

Hops were originally introduced into England from the Netherlands in 1524. They were first mentioned in the English Statute Book in 1552 in the reign of Edward VI, and by Act of Parliament in 1603 hops were then produced in England in abundance.

The functions of hops, the female flowers of the hop plant (*humulus lupulus*), in brewing are manifold. The principal resins—soft resins—confer the bitter flavour and tonic properties found in beer ; and what Hayduck termed a first resin acts as a preservative by inhibiting the action of bacteria. The distinctive and more or less delicate aroma (according to the type of hops used) imparted to beer is yielded by the volatile essential oils existing in the hop flowers. Much of this aromatic oil is evaporated in the brewing process for reasons explained later. Considerable difference of opinion exists as to the true function of tannin in hops. Brewers of wide experience adhere to the theory that tannic acid combines with certain refractory proteins in the wort which will not coagulate with boiling, forming insoluble tannates that are subsequently precipitated. Tannic acid, which is derived from the hop leaves, therefore acts as a cleansing agent, thus indirectly preserving the finished beverage. Hops also contain an alkaloid which formerly, with heavy hop rates, might account for the narcotic effect the heavier beers produced on some consumers. This effect is not, it is asserted, obtained when drinking lager beer, owing to the smaller proportion of hops employed in this type of article. It should be remembered, however, in this connection that the lager beers of the Continent are fermented at low temperatures, yielding low type alcohols as compared with the higher class of alcohols produced from the higher fermenting " heats "



(1) WORCESTER MATHON (2) BRAMBLINGS
(3) FUGGLES (4) CANTERBURY WHITEBINES

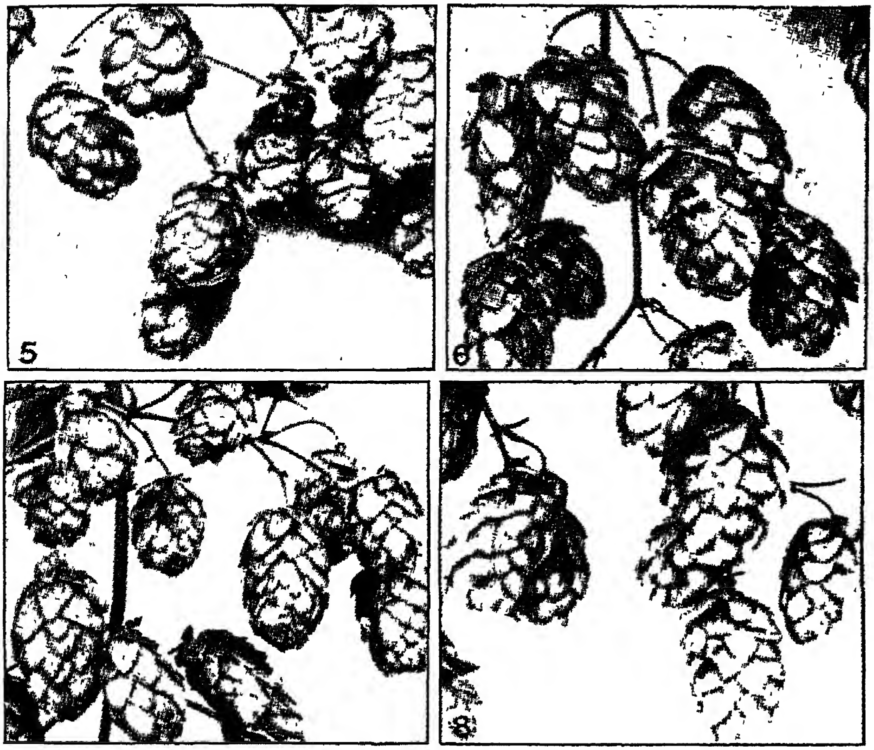
SUMMARY OF CHARACTERISTICS AND ORIGIN OF THE VARIOUS HOP CLASSES ILLUSTRATED*

No. 1. Worcester Mathon.—A Whitebine, grown originally in the parish of Mathon, a few miles from Worcester. A very old mid-season variety and identical with the Canterbury and Farnham Whitebines. Of the very highest quality, both for flavour and lupulin. Can only be grown successfully in the most favoured climate and soil.

No. 2. Bramblings.—One of the best of the early hops. Originally selected by the bailiff on a farm at Brambling, near Canterbury, and now grown in all the best hop districts. It is of medium size, firm, compact, and sound in section, with a well-closed tip. First extensively planted about 1865.

No. 3. Fuggles.—A mid-season or main crop variety, very rich in lupulin, but somewhat coarse flavoured. In shape the hop is large, square in section, and pointed. The petals are thick and strong, and the basal ones of a dark green colour. The plant is hardy, a heavy cropper, and does well in the stiff, damp land of the Weald of Kent and similar districts, where the Whitebines die out rapidly. The original plant was a casual seedling noticed growing in the flower garden of Mr. Geo. Stace Horsmonden, about 1861. The sets were afterwards introduced to the public by Mr. Richard Fuggle, of Brenchley, about 1875.

No. 4. Canterbury Whitebines.—One of the best main crop hops, of the finest flavour and strong in lupulin. Grown originally at Canterbury, and a very old variety. So closely related to the Worcester Mathon and Farnham Whitebine, they cannot be distinguished from each other, and are, no doubt, one and the same hop.



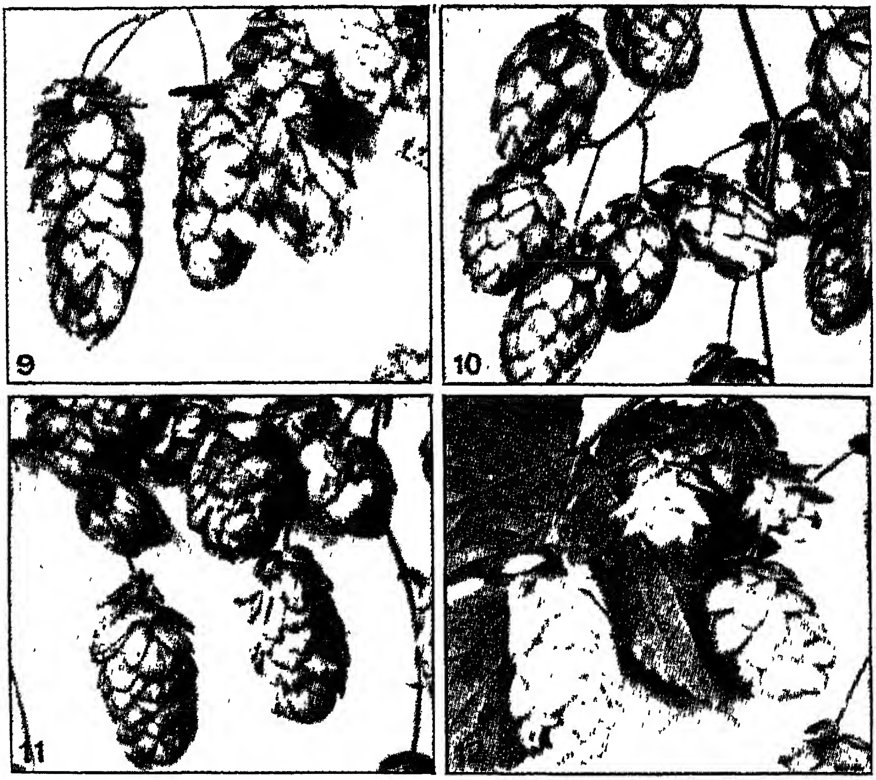
(5) COOPER'S WHITE (6) GRAPES
(7) COLGATES (8) COBB'S EAST KENT GOLDING

No. 5. Cooper's White.—One of the best Worcester hops, and of the Whitebine variety, but not quite equal to the Mathon in flavour. The main points of difference are that the Cooper's White is a more delicate plant, the hops develop rather earlier, and the petals, as will be observed, are larger.

No. 6. Grapes.—So called because the hops grow in thick clusters on short laterals. In shape the hop is long, narrow, square in section and pointed, and is allied to the Fuggle, but is not such an abundant cropper. The Worcester variety is known as the Mayfield Grape and has a better flavour than the Kent variety. When grown without excess of nitrogenous manure, the colour and flavour are good, and it may be considered the best quality of the late hops.

No. 7. Colgates.—The latest hop to ripen, and consequently at times difficult to harvest. In shape a long, narrow hop, square in section, with thin petals, pale in colour. A very hardy variety and heavy cropper, and succeeds best on stiff lands. Has a strong aroma and makes a good yearling hop. Introduced about 1805 by Mr. David Colgate, of Chevening, Kent, the original plant being discovered in a hedge.

No. 8. Cobb's East Kent Golding.—Introduced about 1881 by Mr. John Cobb, of Sheldwich, near Faversham. A medium-sized hop with thin pale yellow petals, good in flavour, but somewhat poor in lupulin. Earlier in ripening than the Whitebines, but not so early as the Brambling.



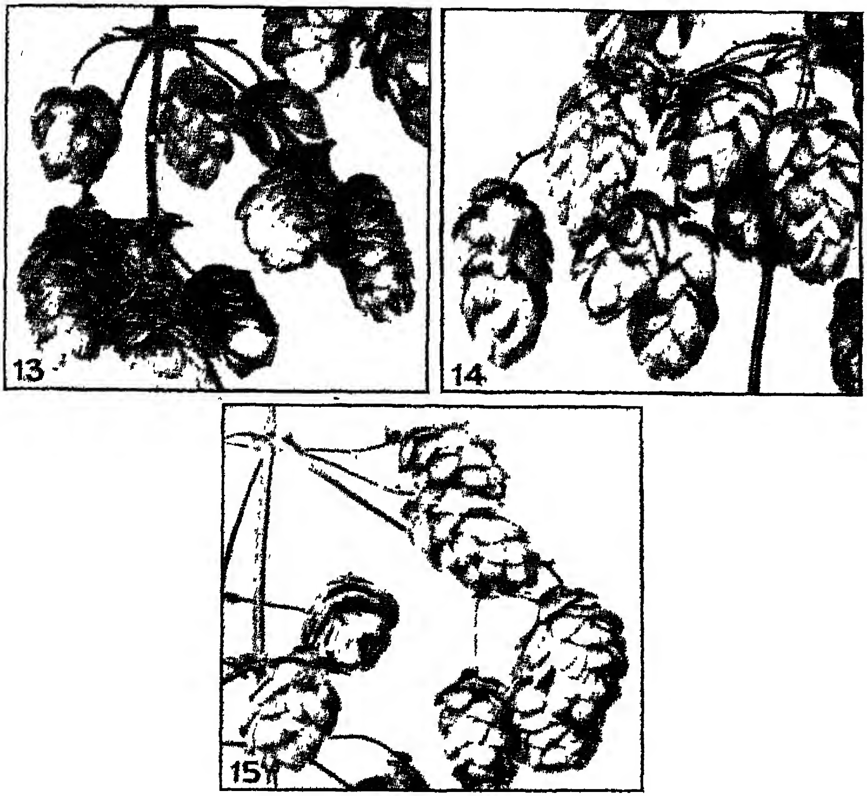
(9) PROLIFICS (10) HENHAM'S JONES
(11) BENNETT'S EARLY SEEDLING (12) WHITE'S EARLY HOP

No. 9. Prolifics.—An early variety. One of the largest hops grown, but of poor quality, coarse in petal, pointed, square in section, and poor in flavour. Grown in districts unsuited to the better kinds of hop.

No. 10. Henham's Jones.—An early variety, similar in appearance to Meophams, but a better kind. Of oval shape and medium size. Somewhat low in lupulin, but of good flavour. Originally raised by Mr. I. Henham, of East Peckham, Kent.

No. 11. Bennett's Early Seedling.—A medium-sized oval hop, rich in lupulin, with a moderate flavour. One of the two English hops (the other being the Fuggle) known with certainty to have arisen from seed. The original plant was raised from seed sown in 1880 by Mr. H. Bennett, of Borough Green, near Sevenoaks. Specially suited for growth on stiff land.

No. 12. White's Early Hop.—In quality one of the best of the early hops. Of medium size, pale golden colour, and excellent flavour, but the plants are delicate and rarely give a satisfactory crop. Introduced about 1852 by Mr. George White, of Hunton, near Maidstone.



(13) AMOS' EARLY BIRD (14) HOBBS' EARLY HOP
(15) MERCER'S RODMERSHAM

No. 13. Amos' Early Bird.—Of good quality, and takes high rank among the best early varieties for cultivation in good districts. Somewhat similar to the Brambling in shape and colour, but earlier. Discovered in 1887 by Mr. Alfred Amos, Wye, Kent, in his garden of Brambling hops.

No. 14. Hobbs' Early Hop.—A long, narrow, pointed hop similar in character to the Prolific, but rather smaller, earlier in ripening, and of a slightly better quality, though it must be classed with the coarse varieties.

No. 15. Mercer's Rodmersham.—A Whitebine hop, earlier than the Canterbury, though not so early as the Brambling. The plant is a good cropper, and the hop rich in lupulin, but the aroma is not quite equal to the best. Selected about 1880 by Mr. R. Mercer, of Rodmersham House, Sittingbourne, from a garden of hops at West Malling, reputed to be the Golden variety, and at least 150 years old.

* Reproduced from the *Official Journal of the Royal Agricultural Society of England*, and abridged by the courtesy of Messrs. G. Gascoyne & Co., Worcester.

adopted in Great Britain. Hops, or rather the cones or strobiles, in addition act as a filtering medium separating mechan·cally all the various constitutents rendered insoluble by boiling the wort. The bitterness of hops is not due to any single substance, but is to be attributed to a number of products which are mostly amorphous. Some of these products are soluble in water, whilst others represent constituents of the resin. One well defined, new crystalline substance which possesses a bitter taste has now been isolated from the resin. Another new crystalline compound of nearly the same percentage composition, but which has an orange yellow colour and is devoid of bitterness, has also been found. The resin of hops contains a large proportion of fatty acids and their esters.

Brewers formerly regarded hops cultivated in particular areas as possessing distinctive brewing properties, irrespective of the climatic conditions which may have obtained in that especial district which they favoured during the development of the burr, while harvesting is proceeding, or at any other period adverse or favourable to the promotion of disease, conditions inseparably connected with the cultivation of hops in this country.

The fact should not be ignored that although the produce of each district has certain characteristics, circumstances may arise during any season which may lessen or increase the peculiar properties to a pronounced extent in either direction. The produce of Kent, and especially East Kent, in addition to containing bittering and preservative qualities of a high standard, were not looked upon as capable of imparting the choicest aromatic and flavouring attributes to the extent yielded by the hops of Worcestershire and Herefordshire. The hops grown in these midland counties were not so many years ago considered to be rich in one quality only, that of delicate flavour and pleasant aroma, and in consequence their use was practically confined to use in the cask or as it is termed

"dry hopping." In addition "Worcesters" were at that time considered to be lacking in preservative qualities, and to deteriorate rapidly during storage.

Hop growers are fully alive to the merits of the qualities distinguishing their hops from those of other competitors in other districts, and they endeavour while conserving these distinctive features to eradicate or minimize properties which find disfavour with brewers. Growers universally have carried out this progressive policy in the improvement of the land, more careful selection of the plant itself, and especially in connection with the kiln drying and curing, with the result that the general characteristics of the hops have altered to such an extent that new methods of valuation must be applied to them. The same remarks apply to the hops from the Pacific Coast States of Oregon and California. Although the preservative powers of "Americans" have always been recognized as superior to English, it is only since 1910, when Professor Adrian J. Brown showed in what measure those characteristics existed in hops from the Pacific Coast, that their importance as a brewing material has become to be recognized by British brewers. It was generally said that the flavour yielded by these hops was so objectionable and pronounced as to confine the percentage it was possible to use within narrow limits. Californian and Oregon growers, however, have spared neither expense nor effort to remove, or at any rate modify, the faults of those produced by growing from "setts" or plants secured from the best types of English hops. In this they were at first only partially successful and the prominent flavour still remained to restrict the use of "Oregons" to from 5 to 10 per cent. Ways and means have been found, however, to eliminate still further the flavour complained of by brewers, and samples of Pacific Coast hops are now on the market which, while still retaining their high proportion of soft resins, tannin, bitter properties and good colour, together with indications of careful kiln management, have a flavour more closely

resembling and comparing more favourably with English hops.

Brewers accordingly have altered the opinion they once held with regard to the qualities of the various growths, and now the brewing value of hops is assessed more on their merits, recognizing that the lines which divided the produce of different areas into separate categories is now less defined than at any period in the history of the trade.

The brewing value of hops is still mainly based on physical examination. Faults of curing are detected by the character of the aroma the sample yields. In many instances the true characteristic aroma of well developed and ripe hops, free from the effects of disease, is marred by either the use of an overdose of sulphur on the kiln, or by permitting the hops to absorb in excess of the sulphur dioxide contained in the fumes from the fires. The correct degree of development and ripeness is observed by the absence of broken portions, and whole cones of hops, moreover, retain more of the essential brewing attributes. English hops are peculiarly susceptible during cultivation to the effects of borne air micro-organisms which produce mould, red rust and blight, all of which affect the appearance, depreciate the brewing value and lower the preservative properties of the hops. The eye plays an important part in the valuation of hops as in appraising the value of most other commodities, but the brewer relies also upon the results obtained from "rubbing down" a sample of hops in the palm of his hand. This simple expedient will inform a keen judge as to the amount and class of aroma, and for comparative purposes will furnish him with a fairly approximate estimate of the amount of "condition" present. By this is meant the lupulin or yellow powder in which is contained the principal resins, essential oil, and the bittering qualities, which together, in the words of the brewer, furnish to the beer that undefinable general "character" so much favoured by the consumer. The aroma yielded by the oil differs

in point of delicacy from the nature and place of origin of the hop. English, especially "Worcesters," are prominent in this particular regard and, as already alluded to, the odour of American hops from Oregon and California, albeit now vastly modified, is still rank. The predominating features of the best types of continental hops from Bavaria and Bohemia and the Burgundy area in France are their high preservative and bittering properties. Prior to 1914 it was considered necessary to employ in the copper proportion of the continentals named in the production of the best classes of bitter ales, the fine aroma being secured from Worcesters added dry to the cask. The soft resins are reduced with age to hard resins, of very low preservative value, if the hops are stored under ordinary conditions at normal atmospheric temperatures. If, however, good sound hops are placed under the influence of cold (35° F.) the resins will not appreciably deteriorate, and the hops will otherwise retain in a remarkable degree their value to the brewer for years. Hence it is that the cold storage of hops is now adopted by brewers universally under ordinary conditions of supply and demand.

A visit to the hopfields dispels many theories. Some of the growers adhere rigidly to the processes adopted by their forefathers, but others are progressive and apply the most modern ideas in respect to cultivation, drying and curing. There is a very general impression that sulphur is only employed by unscrupulous growers to produce a fictitious colour and improve the appearance of weathered hops. Apart from the brown colour contracted by over-ripeness, disease, wind and rain, all hops are picked green, and the glorious primrose tint is not acquired naturally but artificially by the bleaching action of the sulphur added to the fire while the hops contain their maximum percentage of moisture at loading on the kiln. The modern grower does not look to colour as an index of ripeness, but examines the seed, and when this is sufficiently hard and brown picking must at once be proceeded with. Further delay until

the stage of perfect ripeness is reached would result in the opening out and drying up of the petals which, together with the lupulin, would be dispersed by every breath of wind. The colour due to ripeness is never quite uniform throughout the cone, whereas the hops bleached by the method explained later on are uniformly one bright tint throughout. Doubtless more sulphur is added than is necessary for sterilization and to retard deterioration, but the grower believes that in bleaching his hops he simply supplies the demand of the brewer. If two samples are submitted equally good in all respects, but one brighter than the other, the former will be preferred by the average brewer. Hop "oasts," or kilns, like malt kilns, sometimes exhibit in working a deficiency in up-draught, and the super-saturation of the reek which occurs, of course to a variable extent, results in the top layer of the hops being wet, while the bottom part of the load has reached the curing stage. The grower obviates this by "turning." An objection to turning is the fact that it disintegrates the hop cones. The hops are loaded to a depth of from 10 to 15 inches on the old fashioned oast; but this wide range of depth, as well as the period of time necessary to secure thorough drying and curing, is regulated by the drying capacity of the kiln which often differs somewhat widely on the same farm. Thermometers are seldom employed, registration of temperatures, except in very few instances, being ignored. The kilnmen simply rely on their hand for an indication when the hops have reached a dry condition, the stalks breaking easily under the touch.

Maltsters are aware how difficult it is to regulate the temperatures on malt kilns, and when one considers that both the drying and curing of hops must be completed in one-tenth of the time given to malt, it will be seen how impossible it is to avoid irregularity of temperatures, over-heating, and forcing. A very wide range of heats from as low as 75° F. to as high as 160° F. is not unusual on the original type of oasts. The

normal percentage of moisture present in the hops at loading is 75 per cent, which is reduced to 10 or 12 per cent when curing is completed. The hops are then unloaded to the cooling room, where they re-absorb moisture with great avidity. At this stage care is exercised to prevent an excess of moisture being taken up, which results in the hops being "cold bagged," with consequent quicker deterioration in store. On the other hand, the hops must not pass forward to the presses too dry or hot, or the pressure, which reduces them from one-half to a third of their original bulk, will break up the cones, when they will pulp or mash in the copper, or if used for dry hopping trouble may be looked for from "fliers" in the cask.

Nearly 25 years ago growers came to the conclusion that in order better to meet the requirements of the brewer, and the severe competition, especially from abroad, some method should be evolved to overcome the disadvantages and irregularities inseparably connected with drying and curing by ordinary fire kilns—a system, in fact, to ensure more uniform and reliable results. They found that the superiority in preservative value of many continental and American hops was due to the conservation of the soft resins and the volatile essential oils. In Germany this was accomplished by drying on floors in the open air, followed by curing on fire kilns, but at lower finishing temperatures than is customary here, and in America by drying and curing by hot air, also at low temperatures.

The hot air system was introduced in England in 1901, since when the larger cultivators have installed plants similar in principle. The necessary plant consists of boilers of sufficient steam-raising capacity to supply power to the engines which drive the fans, and to heat the 1-in. pipes which are arranged vertically in rows directly in front of the fans in such a manner as to obstruct the free passage of the cold air which thus more readily absorbs the heat from the pipes. The boilers are maintained at a pressure of 50 to 60 lb.,

and the fans, of very large diameter, are driven at a speed of 500 revolutions per minute. The following example may be taken as typical of the enormous volume of hot air which is passed through the hops on this system: A kiln with a double floor—the area of one floor being 34 ft. by 26 ft., and of the other 40 ft. by 20 ft.—has 30,000 cubic feet of air driven through both loads per minute. The most important factor being the maintenance of uniform temperatures, the thermometers employed are similar to the clock-type Bourden pressure gauge of a boiler, and are placed in positions to enable the engineman to readily adjust variations in temperature. This is, however, to a certain extent corrected automatically. Should the boiler pressure recede, thus reducing the temperature of the steam content of the pipes, the engines are governed to drive the fans at a lower rate of speed so that the suction of cold air is lessened in volume and *vice versa*. Drying commences at a temperature of 100° F. and when the bulk of the moisture has been expelled from the load this is increased to 120° F., and finally the hops are cured at a temperature not exceeding 125° F. Some growers on this system "finish off" at 150° to 160° F., a temperature at which, however, the volatile essential oil of the hops is quickly dispelled. The floors of the kilns are composed of laths placed fairly wide apart, upon which a porous horsehair cloth is laid. Of the total area of a kiln some 60 per cent is, therefore, free air space, which allows the blast of hot air to penetrate through the heavy load of hops with ease. The hops, indeed, lie so lightly that no turning of the cones is considered necessary by some growers. Those who do so, however, have a travelling platform erected in the kiln, upon which the men stand while thus employed. In either case, therefore, the finished product meets the wishes of the brewer, as the cones are unloaded practically as whole as when they left the field. To preserve them still further in this unbroken condition, the horsehair cloth is worked on

rollers, which, on being wound, precipitates the hops on the cooling-room floor. The growers claim that, whereas by the old-fashioned open fires the total resin amounted to an average of 14 per cent, by the hot-air system of lower and more uniform temperatures this is increased to 18 per cent, which places their hops more on a level with those of their continental and American rivals.

The question may be asked, by what means does the former make up in the hot-air system for the exclusion of the products of combustion obtained in a fire kiln? The answer is, that by this method there are no uncertain factors to be reckoned with, as nothing passes through the hops but pure country air heated, plus the SO_2 gas from arsenic-free sulphur. The sulphur is burnt on the fires, or in a pan adjacent to the ordinary kiln, and the sulphur dioxide (SO_2) produced combines in its passage through the load with the moisture present in the hops. If the draughts are defective and any cooling action occurs there is a danger that the sulphur may become sublimed; in other words, it may re-condense and remain in the hops. Curing without the addition of sulphur results in only a slight increase of colour in the hops; whilst with it the cones open out more and a better odour is obtained. In the hot-air kilns the sulphur is burnt in stoves erected outside the kilns and the SO_2 produced is conveyed by fans through a pipe to the bottom of the hop floor. Dense volumes of black sulphurous fumes proceed from the kilns, and a comparison between the colour of the hops at loading with that of the cured hops in the cooling room is astonishing. The greater the amount of moisture present in the cones when the sulphur is added the quicker and more effective will be the bleaching action. In point of fact, the grower resorts to sprinkling his hops with water should they be loaded dryer than usual, and in the case of two floors, the contents of the upper one which receives the moist reek from the lower is bleached quicker than the hops on the latter.

CHAPTER IV

BREWING PROCESSES
COMPOSITION OF MATERIALS EMPLOYED AND BREWING CALCULATIONS

THE first consideration requiring attention in connection with the preparation for the initial stages of beer production is to decide upon the quantity of "wort" and its specific gravity to be collected for fermentation into beer. "Extract" refers to the matters in solution present in the total volume of wort, as represented by its specific gravity, extracted from the malts and adjuncts used, which together constitute wort.

Prior to 1880, when the fiscal charges were levied in the form of a tax on the malt produced, brewers assessed the specific gravity of their worts in terms of "Brewers pounds per barrel." This standard was based on the difference between the weight avoirdupois of a barrel of water (36 gallons) and that of a similar volume of wort. A barrel of water at 60° F. weighs 10 lb. per gal. or 360 pounds, and in the case of a barrel of wort weighing 380 pounds, the excess weight of 20 pounds would be therefore expressed as "20 brs. lb. per barrel." When a duty on beer was substituted for malt tax, the Excise officers transferred their activities from the maltings to the brewery where they have since controlled and supervised operations. Somerset House at that juncture adopted their own method of determining the specific gravity of wort. This is founded on the difference between the weight of 1,000 parts of water at 60° F. and an equal volume of wort. In other words, instead of continuing the brewers' standard measure of a barrel of 36 gals., 100 gals. at 10 lb. per gal. was adopted as the unit. It follows that the Excise standard

of 1055 upon which the duty on beer is levied and 19·8 "brs. lb." is precisely the same specific gravity, although expressed in different terms, inasmuch as the former is based on a unit volume of 100 and the latter on 36. Both standards may be found employed in the same brewery, as the original method if correctly applied lends itself to a greater degree of exactitude in practice, and the use of the Excise scale is confined to the compulsory declarations, or entries, of specific gravities by the brewer in the official brewing book. Mathematically, the relation between the original method of assessing the specific gravity of wort and that introduced as the basis of measurement by the Inland Revenue is as 36 to 100, and the conversion of one standard into terms of the other is therefore readily determined by either dividing or, on the other hand, multiplying by ·36. Thus 55 is converted into brs. lbs. $(1055 - 1000) \times \cdot 36 = 19\cdot 8$ "brs. lb.," or to reverse the procedure $19\cdot 8 \div \cdot 36 = 55$ specific gravity. Instruments known as "Saccharometers," when immersed in samples of wort, indicate its specific gravity on either or both scales on the same stem with sufficient exactness to serve all practical brewing purposes, although weighing with a specific gravity bottle must be resorted to when results of precise accuracy are rendered necessary.

The Customs and Excise stipulate that each class of substance utilized for brewing should yield a minimum amount of extract, regarded as the "presumptive yield." There are a number of standards for sugars mainly dependent on their moisture percentage: 256 lb. of invert, glucose, and a number of saccharine substances derived from cereal sources are presumed to yield an extract equivalent in amount to the statutory "presumptive yield" from one quarter of malt. The moisture in sugar is estimated by multiplying the solution extract per barrel by the factor 2·66, thus reducing solution weight to real weight. Example—

Solution extract 35·15 lb.

$\therefore 35\cdot 15 \times 2\cdot 66 = 93\cdot 499$ lb. of soluble solid matter.

If 112 lb. contain 93·449 lb. of solid matter, what will 100 lb. contain.

$$\frac{93{\cdot}499 \times 100}{112} = 83{\cdot}48 \text{ per cent of solid matter,}$$

$\therefore$ 100 − 83·47 = 16·53 per cent of water.

The "presumptive yield" of a quarter (336 lb.) of malt is fixed by the Department of Customs and Excise, and Excise at 4 brs. (36 gals.) at a specific gravity of 55° or 19·8 "brs. lb." per qr. mashed, equalling an extract of 79·2 brs. lb. But a skilled and thoroughly trained brewer can readily obtain from 95 brs. lb. to 100 brs. lb. per quarter from correctly manufactured malt, and while he reckons upon the actual yield from sugars as a constant factor he bases his calculations in respect to malts on the average yield it is customary for him to obtain in practice.

Assuming therefore that he arranges to brew 100 barrels of wort at 15 brs. lb. to be obtained from 25 per cent of invert sugar—yielding in extract of 35 brs. lb. per cwt—the remaining 75 per cent to be extracted from a mixed grist of home and foreign malts yielding 95 lb. per qr. he proceeds as follows—

Brls.		Brs. lbs.		Brs. lbs.	
100	×	15	=	1,500	total extract required.

$\therefore$ 1,500 × ·25 = 375 "brs. lb." from sugar $\frac{375}{35}$ brs. lbs. per cwt. of sugar = 10·71 cwt.

For reasons of expediency 11 cwt. would be used, furnishing an extract of 385 brs. lb., which amount would be deducted from the total brewing requirements, leaving 1,115 brs. lb. to be supplied by the blend of malt—

$$\frac{1{,}115}{95} = 11{\cdot}73 \text{ qrs.}$$

A bushel being the smallest measure in a maltings or brewery, 11 qrs. and 6 bushels of malt would be used together with 11 cwts. sugar.

On completion of the brew the actual result obtained is checked for comparison with the estimated yield.

Suppose 100·9 brls. at 15·1 brs. lb. were collected

$$\therefore\ 100{\cdot}9 \times 15{\cdot}1 = 1523{\cdot}59$$

$$385$$

Less 11 cwt. × 35 brs. lb. from invert sugar = 1138·59

$\therefore\ \dfrac{1138{\cdot}59}{11{\cdot}75}$ qrs. malt = actual extract obtained from malt 96·9 brs. lb.

It should be here noted that under the Malt Tax a flat rate was levied on the malt manufactured, so that a skilled brewer, with the assistance of a fully equipped brewing plant, who obtained a high extract yield thus secured the benefit of such increment free of duty. Under the present fiscal regulations a brewer is deprived of such monetary advantage inasmuch as the duty is charged on the entire volume and specific gravity of the wort collected. On the other hand, in the event of the aggregate monthly produce being below the Excise "presumptive yield" by over 4 per cent, the duty charge is placed on the brewing materials used calculated on the respective minimum presumed rates of extract already referred to.

When the gyle or brew is completed the total volume in the collecting or fermenting tuns is gauged by means of a dipping rod, and the specific gravity of the wort in each vessel is determined. It is essential for this purpose, in order to secure correct results, to adopt the use of a glass saccharometer with the stem widely divided into $\frac{1}{10}$ of "brs. lb." and very clearly defined to facilitate exactitude in registration. In the case of the particular brew we have cited the 15·1 brs. lb. would have to be converted into the specific gravity terms of the Customs and Excise for declaration in the official brewing book, thus $\dfrac{15{\cdot}1}{{\cdot}36} = 41{\cdot}9^\circ$ specific gravity charged at 41°.

The net duty payable is calculated as follows—

Brls.

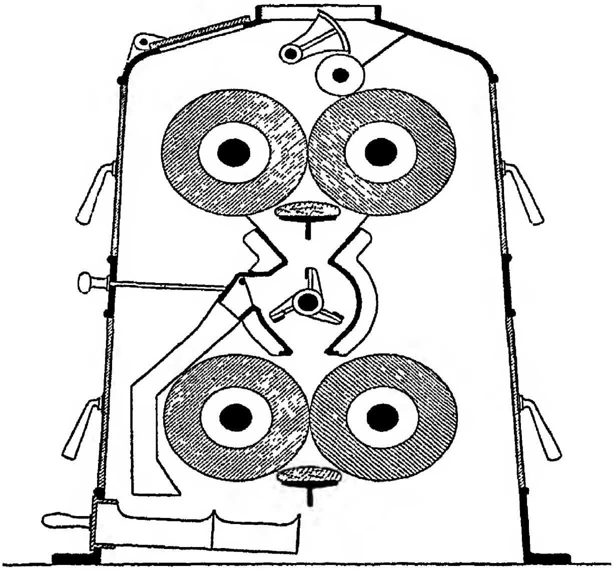
$$100{\cdot}9 \times 41^\circ = 4136{\cdot}9^\circ$$

$$\therefore\ \frac{4136{\cdot}9^\circ}{55^\circ} \text{ - standard Excise gravity}$$

= 75·21 standard barrels from which an allowance of 6 per cent is deducted for waste in fermentation and racking.

$$\therefore\ 75{\cdot}21 \times {\cdot}06 = 4{\cdot}51$$

75·21 − 4·51 = 70·7 net Excise barrels at 100s. per barrel = £353 10s. From this a rebate of 20s. is allowed



INTERIOR OF DUST-PROOF FOUR-ROLLS MALT MILL
(*Messrs. R. Boby, Ltd., Bury St. Edmunds*)

upon the *bulk* barrelage collected, less the customary 6 per cent for waste.

∴ 100·9 brls. × ·06 = 6·05

100·9 − 6·05 = 94·85 barrels at 20s. = £94 17s. 0d.

∴ Primary Duty Charge	£353	10	0	(as above)
Less Rebate on bulk	94	17	0	
	£258	13	0	net amt. payable.

The following is the adjusted percentage composition of the extract yielding materials based on the actual results obtained, which information serves as a working guide in calculating future brewings—

TOTAL EXTRACT

1523·59 :	385	Extract from Sugar :: 100 : =	25·27% Sugar
1523·59 :	1138·59	,, ,, Malt :: 100 : =	74·73% Malt
	1523·59		100·00 %

The following calculation will furnish an estimate of the Dry or Solid Extract obtained per quarter of malt used. If a gallon of cane sugar weighing 16 lb. be placed in a barrel of water, a gallon of water is displaced. Thus, the weight of the vessel's contents will have been increased by 16 lb. and decreased by 10 lb. (weight of a gallon of water). The net increase of weight is, therefore, 6 lb. and the specific gravity, in terms of "brs. lbs." of the sugar solution is 6 brs. lb. per barrel.

∴ Solid Extract : lbs. per barrel : 16 :: 6 per br. or Solid Extract per quarter : lbs. per qr. :: 16 : 6

∴ Solid Extract per br. or qr. = lbs. per br. or qr. $\times$ 2·6 (about) – 2·597 more accurately representing the above factor.

The solution extract of the brewing under discussion is 96·9 brs. lb. per quarter ; and the question now arises what does this represent in terms of dry or solid extract ?

$$96{\cdot}9 \times 2{\cdot}597 = 251{\cdot}64 \text{ lb.}$$

The blend of malt next requires consideration. The functions of foreign malt are various. The husk of British barley is thin in texture and the "grist" or crushed malt produced from home-grown grain is disintegrated in the mills to an extent that interferes with the efficient drainage of the wort from the mash-tun. On the other hand, the cellulose composing the husk of foreign grown barley malt is of a type that resists to a greater degree the disintegrating action of the mill rolls. An admixture of foreign malt with home is therefore necessary to ensure buoyancy of the "goods" (mashed malt) in the mash-tun and to promote correct drainage, in the absence of which loss of valuable extract would result. Buoyancy is essential, and the proportion of foreign malt required depends primarily on the type of mill and the class of home malt used.

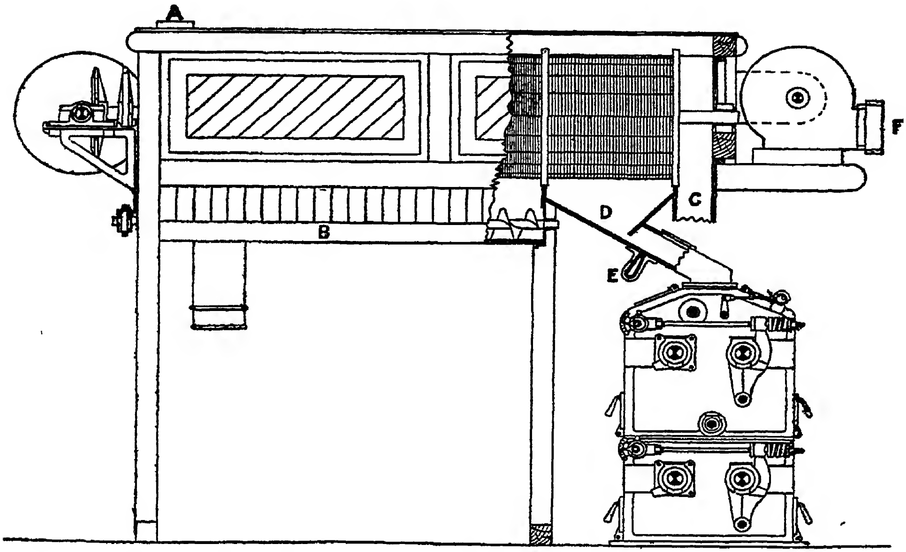
CHAPTER V

MALT CRUSHING

THE malt is first crushed by the top pair of rolls (shown in the illustration). The coarse grist then passes to the explosion preventer, fixed below the rolls, thence to the beater which separates the crushed grits from the husks. Grits and husks then pass to the second pair of rolls under which is a second explosion preventer. These rolls run at a higher rate of speed and any hard ends or large grits are reduced. The finished grist is thus composed of medium sized grits, or nodules, large flaky husks (which facilitate drainage in the mash-tun) free from adhering particles of hard and unbroken malt, and a minimum of flour. Where a single pair of rolls is made to serve for the efficient crushing of all grades and types of malt composing the grist, excessive disintegration occurs, to overcome which the percentage of foreign material must be higher than where a four or six-roll mill of improved pattern is utilized. Milling machinery of this class is fitted with mechanical devices which secure a better admixture of the several malts crushed, obviates excessive disintegration, and permits of the successful use of higher proportions of home malt. Foreign malt, moreover, performs other functions than ensuring improved conditions of drainage. Owing to the extract yielded being of a higher general standard of purity, foreign malt acts as a diluent of the crude proteins and cellulosic tissue ordinarily present in wort dissolved from British barley malt. With this knowledge before them brewers rely on the malt from foreign barley, in conjunction with virtually protein-free adjuncts such as sugar, to safeguard themselves from the risk of instability and lack of brilliancy in their finished beers.

The blend of malts decided on, after screening and

crushing, in some instances falls direct into the grist case fixed directly above the mash-tun, or is consigned to the former receptacle by elevators or archimedean screws, or both.



EXTERIOR OF FOUR-ROLLS MALT MILL WITH SCREEN AND FAN

(*Messrs. R. Boby ,Ltd., Bury St. Edmunds*)

Crushing is also carried out with a four roll-type of mill, the rollers being set in a parallel position above which is installed a grader. The opinion is held by some brewers that with this class of machine it is possible to grind both large and small corns to a more uniform degree of fineness, ensuring the best results available in the mash-tun. It is argued that this is not possible with mills of English or foreign manufacture in which the malt passes through both sets of rollers.

CHAPTER VI

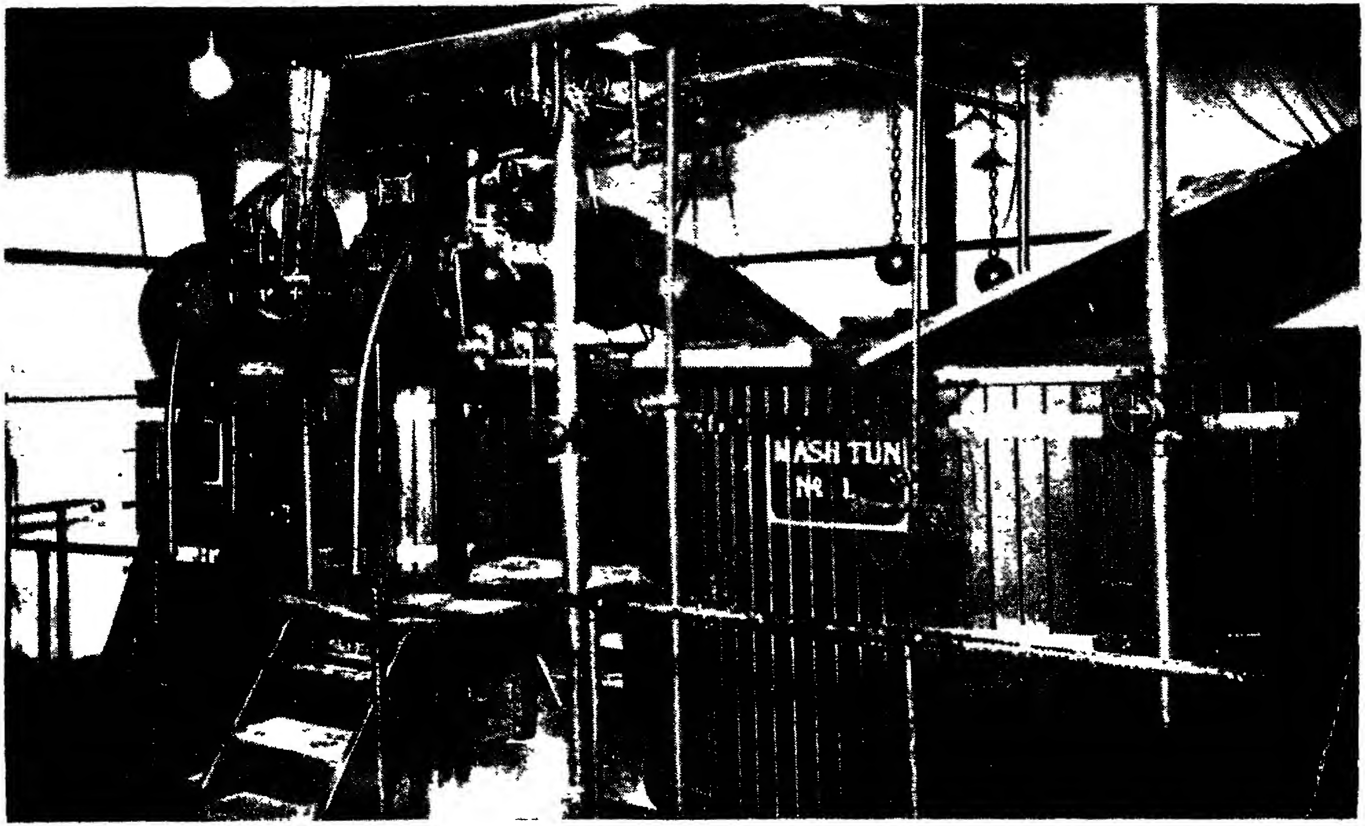
MASHING AND SPARGING

As a preliminary to proceeding with the mashing operation, consisting of mixing the grist or crushed malt with water, the latter, or " liquor " as it is termed, is raised to the required degree of temperature by means of steam coils or other type of heater placed in cast iron tanks.

The deficiency in the water of saline ingredients suitable for the particular beer to be brewed is added to the grist during crushing and at mashing in the manner fully described under the heading of " Water."

The mash-tun is a cylindrical vessel composed of cast iron, fitted with a so-called false bottom covering the entire tun and consisting of a number of drainage plates, usually of the same metal as the mash-tun, but sometimes of gunmetal, chosen for its comparative lightness, or phosphor bronze.

At the outlet of the grist case and commanding the mash-tun is a power driven mashing machine, known as " Steel's " from the name of the inventor. There are other types of outside mixers or mashers in use which are worked automatically, notably " Maitland's," but as better extractive results are obtained from a power driven apparatus, " Steel's " is now the type generally adopted. This item of plant consists of a cylinder in which a rotary shaft is worked horizontally with a number of blades attached, and arranged to effect as complete an admixture of water and grist as possible. The grist enters an aperture at the top of one end of the Steel's machine, and the water meets it by rushing in from the side of the masher. The revolving blades mix the grist and water and carries this mash forward to the mash-tun. Unless the grist case is of true conical form, and especially if it is divided into two compartments



A PORTION OF A MASH-TUN ROOM

to serve two mash-tuns, inequalities of admixture result. To overcome such faults and to secure additional mashing facilities at the disposal of the brewer when required, mash-tuns are fitted with power driven rakes.

Water can be run into the mash-tun either by means of an " underlet " or the flowing of water through pipes installed underneath the mash-tun plates, or, on the other hand, by distribution in a fine spray over the surface of the " goods " (mashed malt) by means of a revolving sprinkler or " sparger." Thermometers are fixed in the main pipes and branches, and any temperature of water desired for mashing, underletting or sparging can be secured immediately by the application of either steam or cold water drawn from small subsidiary pipes arranged conveniently for the purpose of raising or lowering the temperature of the main liquor supply.

Before mashing is commenced the mash-tun is heated either by the injection of steam or, as in some breweries, the plates are covered for a period with water at a high temperature.

The temperature of the brewing water, or in brewing phraseology " the striking heat of the liquor," varies widely according to the individual view of the brewer, based on experience of the existing conditions of the brewery, type of beers required, class of materials used, enzymic powers present in the malts, variety of yeast and system of fermentation followed. Under ordinary circumstances the loss between the temperature of the mashing water and that of the completed mixture of grist and water amounts to 10° F.–12° F., which must be allowed for in arranging the " initial heat," i.e. the temperature of the goods on completion of the mashing process. This loss is dependent on various factors such as the ratio of mashing liquor—from 2 to 2¼ brls. per quarter of malt according to the proportion of the lighter foreign present—the specific heat, temperature, and class of malt, and mainly the position of the mash-tun. An increase of heat results from chemical action due to hydrolysis effected by the malt enzymes, but if the

mash-tun is not correctly lagged, or the mashing machine is situated some distance from the containing vessel, the increase gained by chemical action is lost by undue radiation.

The following formula is utilized for calculating the striking heat of liquor to obtain a given initial " goods heat."

a = weight of malt
b = specific heat of malt (– ·42)
c = actual temperature of malt
d = weight of water
e = actual temperature of water

$$\text{Then } \frac{a \times b \times c \times d \times e}{a \times b + d}$$

According therefore to the varied conditions already enumerated " initial heats " may range from 148° F. to 155° F. If the first named temperature or approximate thereto is decided upon, then " underletting " is resorted to by admitting subsequent to mashing a quantity of water from $\frac{1}{4}$ to $\frac{3}{4}$ brls. per quarter mashes, at 170° F to 190° F. below the plates to raise the goods temperature, the rakes being revolved meanwhile to ensure an equable distribution of the water and an ultimate mash of uniform constituency. Care is observed, however, to obviate any excessive agitation by the action of the rakes, otherwise buoyancy of the goods will be interfered with and valuable extract lost in consequence.

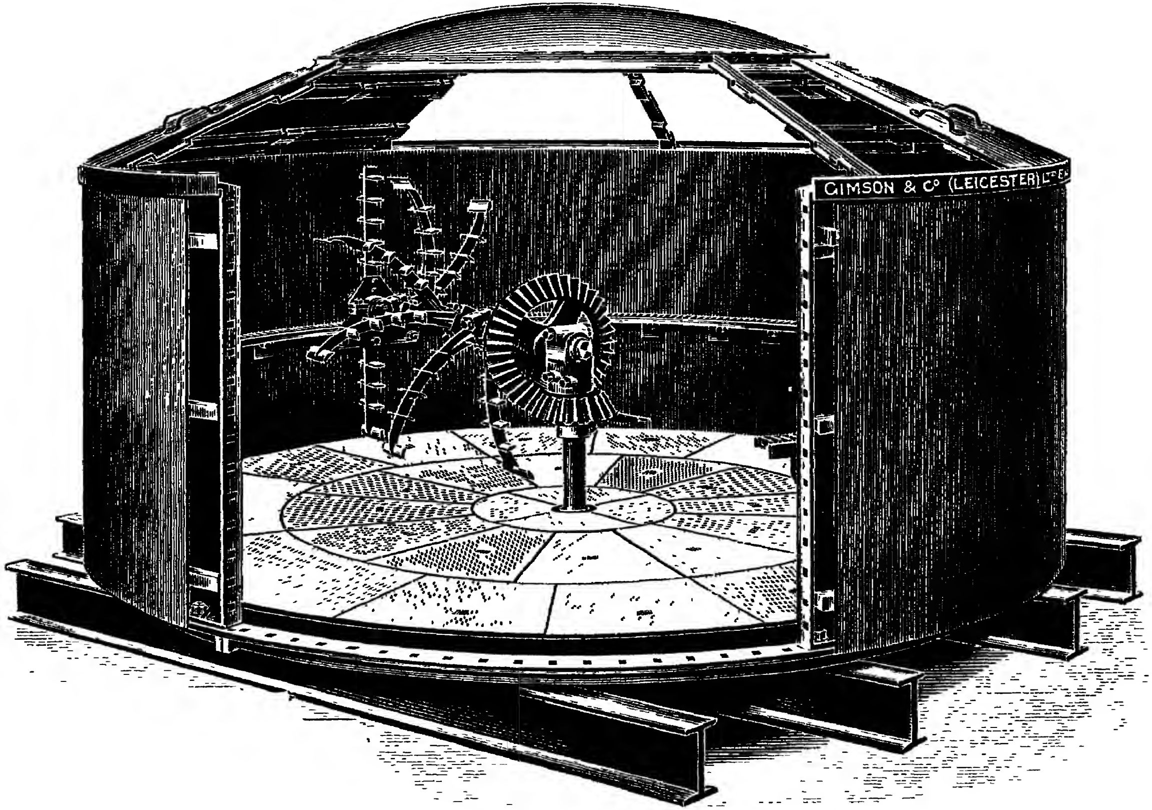
On completion of the initial mashing stage the contents of the mash-tun is allowed to rest, " stand-on " is the expression used, for 2 hours, during which period the bulk of the modified starch will undergo conversion. It is here necessary to explain the nature of the changes which occur in the mash by the bio-chemical agents or " enzymes," a term originally applied to the digestive ferments such as pepsin, trypsin, and ptyalin in the saliva. The word " enzymes," as mentioned earlier, has now been universally accepted as the name of a

group of chemical bodies, products of living cells, which have the peculiar property of affecting the chemical operations of living matter but which do not enter into the final products of these reactions. As will be seen later, and can be observed by referring back to the description of the malting processes, temperature plays an important part in the control of enzymic reaction: each enzyme has a maximum, a minimum, and an optimum temperature of activity, and if heated above the maximum coagulation results and the enzyme will in consequence be rendered inactive and finally destroyed. There are four classes of enzymes, but in the present connection two only need be mentioned.

(1) The hydrolyzing enzymes such as diastase and peptase, which cause the addition of water to carbohydrates and proteins respectively in the processes of digestion, and

(2) Those such as zymase which split up bodies into simpler products without any hydration.

Apart from the subsidiary constituents of malt, in amount, the principal extract yielding substance of interest to the brewer is starch, which comprises over 60 per cent of the entire weight of malt. Of this proportion, the bulk is modified in the malting process by the dissolution of the cellulose wall surrounding the starch, which thus liberated lends itself more readily to conversion by diastatic action at the comparatively high temperatures adopted for mashing and sparging. The action may be here briefly described. On mashing, the free or semi-free starch is at once gelatinized, or converted into starch-paste, which is then acted upon by liquefying diastase and the paste is degraded to starch solution. In this form it is reduced to sugar or saccharified by the saccharifying diastase into the wort sugars dextrin, malto-dextrins, and maltose. *Dextrin* is always produced first and in a definite amount, forming one-fifth of the original starch. It resists a further reduction and is unfermentable, hence the appellation "stable-dextrin." *Malto-Dextrins* vary in



MASH-TUN, SHOWING RAKES AND DRAINAGE PLATES, OR " FALSE BOTTOM "

(*Messrs. Gimson & Co., Ltd., Leicester*)

composition, dependent upon the activity of diastatic action, which is regulated by the amount of diastase originally present in the malt and the temperature of the striking liquor at mashing. High diastatic power aided by low working temperatures produce malto-dextrins in which the maltose ratio predominates, and *vice versa*. Malto-dextrins as such are quite unfermentable in the primary fermentation by the yeast *S. cerevisiae*, but they undergo reduction to maltose by the further action of diastase ; and certain forms of supplementary or secondary yeasts in the cask can reduce them, although but slowly, to dextrose which is then fermented.

Maltose is the ultimate sugar product resulting from the action of diastase in the mash-tun. Maltose is further reduced by the enzyme *maltase* during fermentation to dextrose which is wholly fermentable.

Certain of the modified proteins present in malt are rendered soluble and diffusible during mashing, thus serving either as yeast nutrients or imparting palate-fullness to the beer by the action of *Peptase*. The activity of this enzyme in the mash-tun is analogous to that of diastase, and while the latter degrades starch to simpler substances the former changes the molecular composition of albuminoids in a similar manner under the same influences in respect to temperatures, fluidity and duration of the infusion period in the mashing vessel. The primary products of the action of Peptase are Peptones, and the final result is the production of chemical compounds known as Amides and Amino-acids.

The latter bodies furnish organic nutriment for the yeast and also certain bacteria under favourable conditions—and Peptones in a less degree serve the same function—in addition to which the presence of the unabsorbed portion of the latter in beer confers so-called body to the finished beverage.

Enzymic action both of diastase and peptase requires a slightly acid medium, and hence it is that in some

breweries where the brewing water contains carbonates which neutralize the normal acidity of the mash, edible lactic acid is added to the water or the goods in the mash-tun.

At the termination of the "standing on" or resting stage of two hours duration previously alluded to, the taps of the mash-tun are partially opened and the worts are run off—slowly at first—to the "copper" or boiling vessel, the volume of wort withdrawn being replaced by a similar quantity of water at a wide range of temperatures distributed equally over the surface of the goods by the sparge, which apparatus is actuated by the pressure of the water. This extraction process which occupies from 3½ to 4½ hours, dependent on the degree of modification of the malt and the system of milling in vogue, is maintained without interruption until the goods have been practically exhausted of their soluble contents. That is, the specific gravity of the "first runnings" of the wort from the "spend-pipes" may register from 30 to 33 brs. lb. per barrel, or 84 to 92 degrees, and the "last runnings" record as low as ·5 brs. lb., or between 1 and 2 degrees on the Excise scale.

CHAPTER VII

THE BOILING OF THE WORT

THE wort is conveyed either direct or through subsidiary vessels, " under-backs " or " upper-backs," to one or a series of boiling pans or " coppers," a term derived from the metal composing this item of plant. Single " gyles " or brews, or, on the other hand, " parti-gyles " are produced as required. That is to say, the contents of one copper may be confined to the collection of a wort for one class of beer or several, the necessary correction in respect of gravity in the latter case being carried out in a manner to be described later. The sugar employed is dissolved by steam, and the diluted sugar solution obtained joins the wort in the copper.

Boiling the wort is resorted to with the object of serving several essential purposes. Formerly with the brewing of beers of heavy and medium specific gravity, the concentration of the wort by evaporating large volumes of water in the boiling process was always a necessary procedure, whereas wort concentration need not be carried out to the same extent with the present type of brewery products.

Boiling extracts from the hops their soluble constituents, the character of which were described under the heading of " Hops." The tannic acid combines with certain proteins, and there is practical grounds for the contention that the greater the amount of hops the more nitrogenous substances are coagulated and eventually precipitated, so that as their removal preserves the beer hop tannins are regarded as preservatives. Boiling also withdraws from the hops the soft resins wherein lie the most direct antiseptic bodies. Prolonged boiling, however, converts the soft resins into hard, which are of no preservative value. Malic acid is a constituent

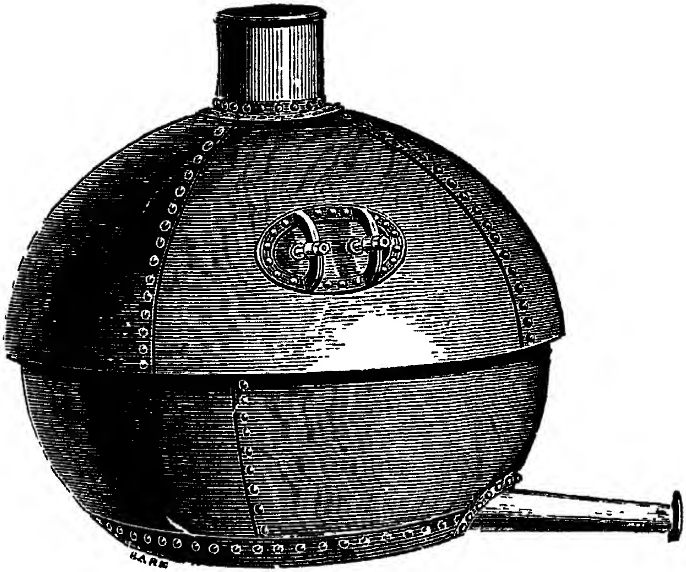
of hops yielded up by the influence of high temperatures, and, in addition to conferring a certain measure of undefinable character to the finished beer, prevents in the latter the growth of disease micro-organisms. The hop oils also dissolve in the boiling wort, but much of the aromatic properties which these oils contain are dissipated in the boiling process, hence the reason for adding hops of delicate aroma to the cask.

Sterilization of the wort is accomplished by boiling, aided by the sterilizing influence of the acid and antiseptic constituents of the hops. One of the most important results of boiling is the fixing or "stabilizing" of the wort by destroying the enzymes diastase and peptase, in the absence of which no further degradation of carbohydrate or protein constituents can occur at this stage; and an equally essential factor of importance secured in the copper is that directly a high temperature is reached certain proteins coagulate.

Ebullition of the wort is maintained for from 1½ to 2½ hours—generally 2 hours—during which period a temperature of 214° F. to 218° F. is registered, dependent upon the depth and specific gravity of the wort, with ordinary dome fire coppers correctly set, but considerably higher temperatures are reached with closed coppers in which a pressure is generated. In the case of the latter, or when a copper of exceptional depth is installed, caramelization of the carbo-hydrates occur, and certain of the rank bitter properties of the hop are extracted, which factors adversely affect the flavour of the finished beer. On the other hand, shallow coppers permit of undue evaporation involving an excess loss of the aromatic qualities present in the hop oils, and at the same time lower the wort temperature to a degree which is insufficient to extract the resins and the tannins in the hops.

Steam wort boiling vessels are also used, and offer advantages over fire coppers with regard to economy of working. The latter requires direct firing with best quality coal, whereas with a jacketed wort pan no

separate labour is involved as steam is conveyed from the boilers and passed through a reducing valve at a definite pressure maintained without intermission throughout the entire boiling period. The condensed steam, moreover, furnishes a valuable source of hot water supply which can be utilized for general brewery washing purposes, or serve as feed-water for the boilers.



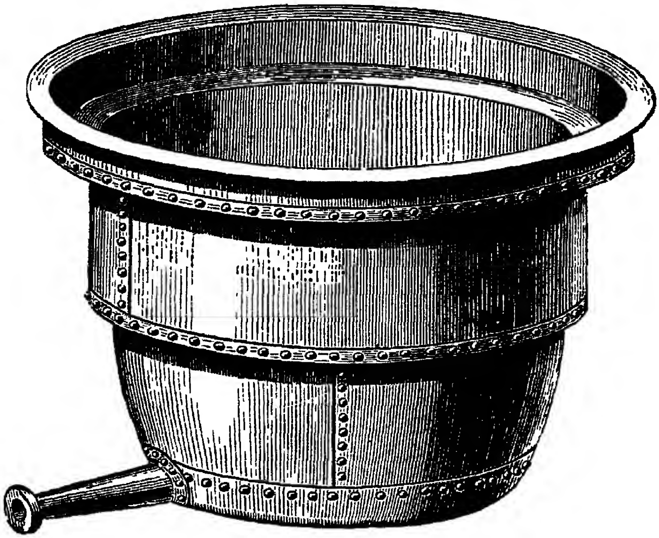
WORT PRESSURE COPPER

(*Messrs. S. Briggs & Co., Ltd., Burton-on-Trent*)

The intense heat, however, to which the entire contents of a fire copper is subjected under the normal principle of convection confers a distinctive cooked flavour to the finished beer. When steam-jacketed coppers, or coils, are employed, it is obvious that the maximum temperature of the heating medium is low as compared with the calorific power liberated by direct combustion from coal. It follows that beers, the wort of which was boiled by steam, have a less pronounced cooked flavour on the palate than the beers obtained from fire

coppers. It is asserted that in the former case the wort is merely "stewed," while in the latter instance real "cooking" occurs yielding beers of enhanced general character.

Hops are added to the boiling wort at rates varying from 1 lb. to 3 lb. per barrel according to the type of beer required, and its gravity, and the age, class, and quality of the hops used. As the characteristics and



WORT FIRE COPPER : OPEN

(Messrs S. Briggs & Co., Ltd, Burton-on-Trent)

brewing value of hops vary, a blend is always preferable. A conflict of opinion exists as to the correct stage at which the hops should be added to the wort. Some brewers add the total weight of hops decided on at the commencement of the boiling process, contending that the entire period of ebullition is required to extract the virtues of the hops, while others aver that only a portion of the normal boiling period should be occupied for the purpose of extraction, and that if this stage is prolonged not only are the volatile and aromatic oils of the hops evaporated and wasted, but that excessive

ebullition converts the valuable soft resins into useless hard resins. Where a number of copper "lengths" are made up the specific gravity of the wort in each boiling vessel is equalized, and the hops are added in true mathematical proportion based on the relation which the extract contained in the several coppers bear to the total yield from materials.

Practically the amount of water evaporated in the course of a definite pre-arranged boiling period serves as an index which points to the thoroughness, or otherwise, of the character of ebullition to which the wort has been subjected. The volume of water evaporated varies in every brewery in accordance with the cumulative effect of the various factors favourable and adverse already explained. But the percentage lost in boiling in any specific brewery carrying out the process effectually and with regularity can be regarded within fairly narrow limits after adjustment for atmospheric conditions as a *constant* which the brewer aims at maintaining. Especially is this true in respect to steam-jacketed coppers, the heating medium being automatically governed. With fire coppers the human element has to be reckoned with, and unless the stoking is conscientiously performed, or is not supervised, the percentage loss in water evaporated is irregular. The loss ranges in different plants from 8 to 15 per cent, calculated on the original quantity of wort collected in the coppers.

On completion of the boiling process the wort is "cast" or "turned out" into the hop-back.

The Hop-back. This item of brewing plant is a round or rectangular shallow tank or back fitted with drainage plates or false bottom similar to that installed in mash-tuns. It acts as an intermediary filtering vessel. When the wort is transferred to the hop-back the hops subside, forming a filter bed covering the entire surface of the drainage plates upon which is deposited the flocculent matter or coagulated proteins. Those combined with the tannins and those rendered insoluble, together

with the glutens dissolved in the boiling wort but which absorb oxygen in the hop-back, become insoluble and are precipitated on the spent hops. Hot aeration of the wort is necessary for reasons explained later. This occurs at temperatures between 180° F. and 190° F., but as it is essential that the casting of the wort from copper to hop-back should be effected with all speed, especially with fire coppers, it is doubtful if hot aeration in the requisite measure occurs at this stage. After a settling period of from 20 to 30 minutes, the hopped wort is carefully drawn off through taps and distributing pipes to the coolers, in a brilliant condition.

In many instances the latter item of plant is, for reasons of securing better atmospheric purity, situated on the highest portion of the brewery buildings in which case the pumping of wort has to be resorted to.

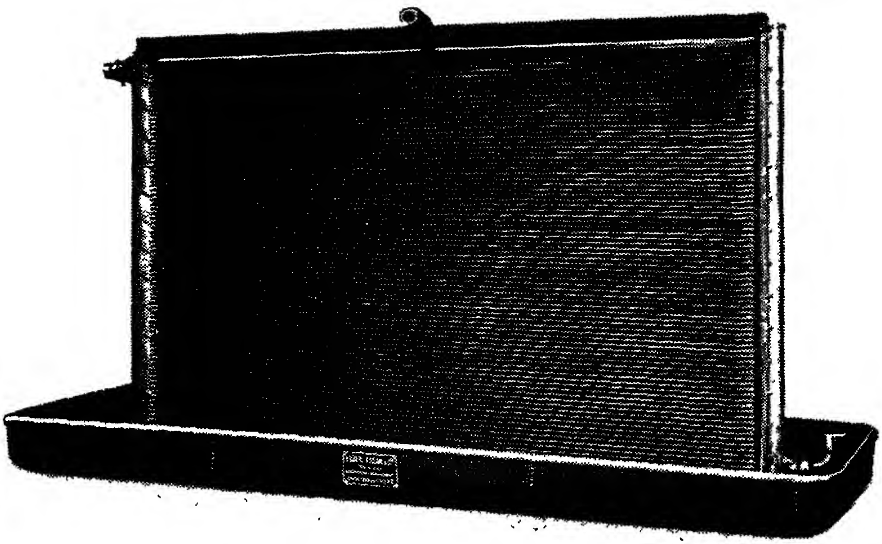
CHAPTER VIII

COOLING THE WORT

Coolers. Up to this stage in a brewing process the wort is technically sterile. Under modern conditions of working the term " coolers " applied to this vessel is a misnomer. Formerly brewers had no other means of reducing the temperature of their wort than permitting it to remain for necessarily long periods distributed over a wide area in one or, in some cases, two shallow open coolers, the dissipation of the vapour and the consequent cooling being assisted by the action of fans. Excessive exposure to atmospheric influences at gradually diminishing temperatures result in contamination with myriads of air borne micro-organisms of disease which ultimately develop readily in the finished beer, the products of such development quickly rendering the beer unstable. The two periods of the year in which the cooling of the wort could be accomplished with less risk from aerial infection were March and October, hence the reasons for the former public appreciation of the brewings produced in the months named. Since the introduction of refrigerators the flavour, brilliancy, and stability of the national beverage is infinitely less variable and it is purer than before, although obviously winter brewed beers exhibit greater keeping properties than those produced during summer, and " coolers " are still employed not actually for the purpose of cooling, but to serve two other definite requirements, i.e. hot aeration of the wort and the precipitation of matters rendered insoluble by such treatment. Brewers owe a considerable debt to Pasteur for enunciating the theory of hot aeration and its importance in connection with securing the brilliancy of beer. He proved that brilliant wort when distributed in the form of a fine film absorbs oxygen which becomes " chemically fixed,"

and in this state it combines with the resins from the hops, forming innumerable minute particles the specific gravity of which, however, is sufficient to form a fairly heavy deposition on the coolers. To secure the requisite amount of hot aeration the wort is transferred from the hop-back to the coolers in a spray through distributing pipes. Immediately the entire fluid contents of a hop-back reach the coolers refrigeration commences. The spent or exhausted hops which form the filter bed in the first named vessel retain a fair quantity of valuable extract, reckoned as 36 gals. of wort absorbed per 60 lb. hops used, and this is recovered by sparging with water at high temperatures (170° F. to 190° F.) in a manner similar to that described in connection with the extraction of the wort from the crushed malt in the mash-tun. The brewer arranges that the total volume of wort collected in the various coppers, allowing for loss by evaporation in boiling (8 to 15 per cent) and subsequently by cooling (from 5 to 10 per cent), will permit of the spent hops being sparged, or "splashed," at a definite rate calculated in gallons per lb. of hops employed. As the total loss of water by evaporation is a fairly constant factor in any particular brewery, the "splash" is utilized up to the definite rate decided on (from 2 to 5 gals. per lb. of hops) to act as a coarse adjustment of the finished specific gravities required of the worts collected in the fermenting vessels. This calculation can be checked at any stage of the proceedings, and any further fine adjustment rendered necessary is carried out by plain liquor apart from the pre-arranged rate of "hop splash," so that both are added to the main bulk of wort on the coolers *without loss of time and at as high temperature as possible.* The transference of the wort to the latter results in a reduction of temperature varying within wide limits according to the situation of the coolers and the speed at which the transfer is carried out. Opinions differ as to the minimum temperature at which infection occurs on the coolers, some authorities place the limit at 170° F., while

others consider that the line dividing sterility from contamination can be lowered to 150° F. There can be no arbitrary limitation ; purity, or otherwise, of environment alone regulating conditions, and these in turn are controlled by the period of the year—or even the hour of the day or night—at which the wort remains on the coolers, and the care, or, on the other hand, the negligence displayed by those in control

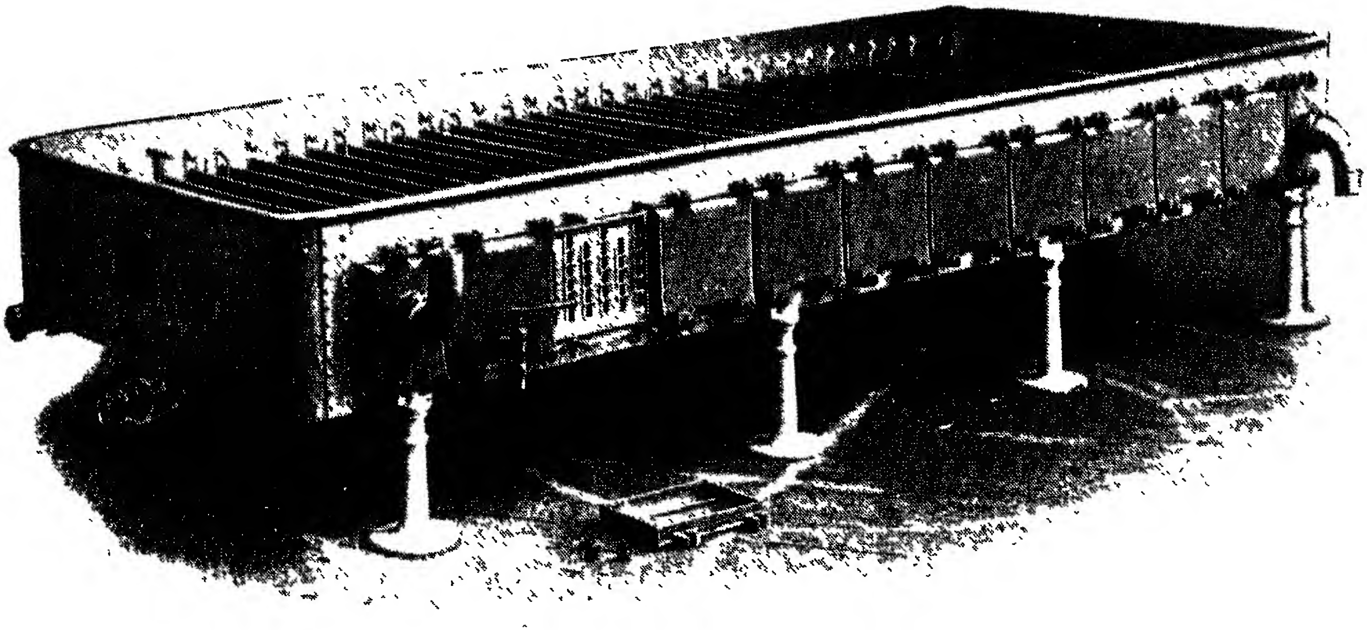


VERTICAL REFRIGERATOR

(*R. Morton & Co., Ltd., Burton-on-Trent*)

in regard to cleanliness, in the removal of dust from cooling and adjacent rooms, and the situation of the brewery.

"**Refrigerating.**" The wort is then passed to refrigerators, and in its course over these machines it is agitated and exposed to the action of the air and is thus subjected to "cold aeration." A vertical refrigerator consists of corrugated sheet copper arranged vertically through which cold or iced water passes upwards inside the



HORIZONTAL REFRIGERATOR

(R. Morton & Co., Ltd., Burton-on-Trent)

corrugations, and this refrigerating medium emerges at the top of the machine. The wort travels in an opposite direction downwards from a pipe which distributes it over the exterior corrugations, and the cooled wort passes to the fermenting vessels where it is collected at from 58° F. to 62° F. Horizontal refrigerators are also used in certain circumstances, but this class of machine does not promote satisfactory aeration or agitation, and it requires double the volume of water, as compared with that used by a vertical machine, to cool a given quantity of wort.

With regard to "cold aeration," already alluded to, the oxygen at this stage is merely dissolved mechanically in the wort, and the aeration serves to provide the yeast with sufficient oxygen to give it a start in life, so to speak, as a ferment. After the yeast has absorbed this free oxygen, it has to rely for a period upon the oxygen yielded by the reduction of the saccharine substances or carbo-hydrates in fermentation, a subject that will be considered under the proper heading.

Parti-gyles. Mention has been made of the fact that a brewer can produce a variety of beers as a parti-gyle from the produce of a single mashing. The following method is adopted.

1. To ascertain in what proportion worts of two different specific gravities must be mixed to obtain a certain bulk at an intermediate gravity.

(*a*) First find the bulk of stronger wort by multiplying the given bulk by the pounds of gravity below the gravity required of the weaker of the two worts, and divide by their difference of gravity.

(*b*) Then find the bulk of weaker wort by multip'ying the given bulk by the pounds of gravity of the stronger of the two worts over the gravity required, and divide by their difference of gravity.

2. To ascertain the proportions in which two worts of different specific gravity must be mixed to obtain an intermediate gravity, find the difference of gravity

of the two given worts above and below the required gravity. State the differences (inversely) in the form of a fraction which then reduce to its lowest denominator.

3. To ascertain the proportions in which worts of four different gravities may be blended in order to produce an intermediate gravity.

(*a*) Ascertain the differences of gravity of all four worts above and below the required gravity, but inversely. This column will exhibit the proportions at the gravities in the same line.

(*b*) Obtain the average gravity of the second, third, and fourth coppers and employing this means as one, and the gravity of the strong wort as the other, proceed as in the method described in 2.

EXAMPLES

1. Required 100 Brls. @ 14·0 " Brs. lb." How much wort at 20 lb. must be combined with wort at 13·0 lb. to produce the above quantity ?

" Brs. lbs." under required gravity, of the light wort (14·0 – 13·0) = 1 lb.

Difference between the two worts employed for blending (20·0 – 13·0) = 7 lb

$$\frac{100 \text{ Brls.} \times 1}{7} = 14{\cdot}29 \text{ Brls. @ 20 " Brs. lb."}$$

Proof— 14·29 Brls. @ 20·0 = 285·8
85·71 ,, ,, 13·0 = 1114·2
100·00 1400·0

$$\therefore \frac{1400}{100} = 14 \text{ " Brs. lb."}$$

2. Required 100 Brls. @ 16·0 lb. to be obtained from worts of the following gravities, i e. 12, 14, and 18 " Brs. lb."

Average " Brs. lbs." under required gravity of the 2 weaker worts (16 – 13) = 3 " Brs. lb."

Difference between the *mean* of the weaker wort and the strong wort (18 – 13) = 5 " Brs. lb."

$$\frac{100 \text{ Brls.} \times 3}{5} = 60 \text{ Brls. @ 18 "Brs. lb."}$$

Proof—60 Brls. @ 18·0 " Brls. lb." = 1080 " Brs. lb."
40 ,, ,, 13·0 ,,
(the *mean* gravity of the 2 weak worts) = 520 ,,

100	1600

$\therefore \frac{1600}{100} = 16{\cdot}0$ " Brs lb."

or

60 Brls.	@	18·0 " Brls. lb."	=	1080	" Brs. lb."
20 ,,	,,	14·0 ,,	=	280	,,
20 ,,	,,	12·0 ,,	=	240	,,
100				1600	

$\therefore \frac{1600}{100} = 16{\cdot}0$ " Brs. lb."

3. Required 100 Brls. @ 15·0 " Brs. lbs." obtained from 4 worts of the following gravities, i.e. 10, 12, 14, and 20 " Brs. lbs "

Average. " Brs. lbs." under required gravity of the 3 weaker worts (15 – 12) = 3 " Brs lb."

Difference between the mean of the 3 weaker worts and the strong wort (20 – 12) = 8 " Brs lb."

$\frac{100 \times 3}{8} = 37{\cdot}5$ Brls. @ 20·0 " Brs. lb."

Proof—37·5 Brls. @ 20·0 = 750 " Brs. lb."
62·5 ,, ,, 12·0 = 750 ,,

100·0	1500

$\therefore \frac{1500}{100} = 15{\cdot}0$ " Brs. lb."

or

37·5 Brls.	@	20·0	=	75·0	" Brs. lb."
20·83 ,,	,,	10·0	=	208·3	,,
20·83 ,,	,,	12·0	=	249·96	,,
20·83 ,,	,,	14·0	=	291·62	,,
99·99				1499·88	

$\therefore \frac{1499{\cdot}88}{99{\cdot}99} = 15{\cdot}0$ " Brs. lb."

PART III
FERMENTATION

PART III

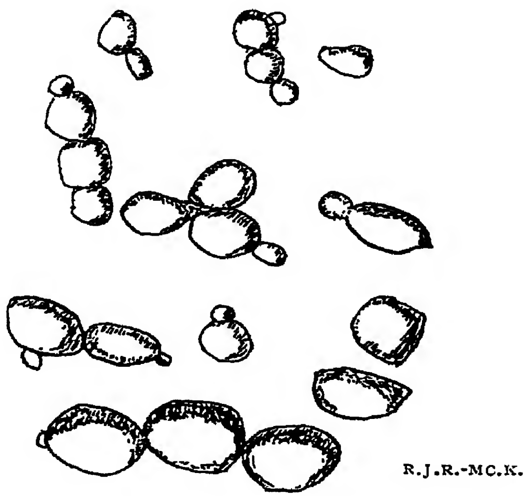
CHAPTER I

YEASTS AND FERMENTATION

THE collected wort is now converted into beer by fermentation through the agency of specially selected yeast. Fermentation is a series of biochemical processes. Formerly it was supposed that maltose was directly fermentable by yeast. In 1898 Croft Hill found that an enzyme, "*Maltase*," is present in malt, and he extracted it from a number of yeasts, including ordinary brewing yeasts. Maltase has the property of reducing maltose in wort to dextrose (glucose) which another yeast-secreted enzyme, "*Invertase*" or "*Sucrase*," under suitable temperatures, reduces by the fixation of water, or hydrolysis, cane sugar into invert sugar composed of dextrose and laevulose in moiety proportions. Brewers, it will be remembered, however, prefer to prepare, or have prepared by manufacturers, their invert sugars by the acid process previous to combining the preparation with the wort, so that the action of invertase is limited to the hydrolysis of the cane sugar normally existing in malt extract.

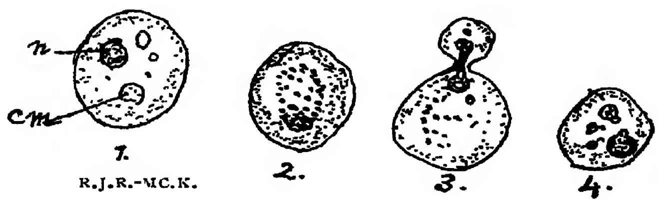
The dextrose from the sources indicated, and to some extent laevulose, are then directly converted into alcohol and carbonic gas by another enzyme, "Zymase," discovered by E. Buchner in 1897. So far we have dealt with the reduction of the sugars to dextrose and the subsequent conversion of the latter to alcohol and CO_2. Proteolytic enzymes, three in number, also exist in yeast: *Peptase,* which breaks down proteins into peptones; *Tryptase* acts similarly on the other proteins, producing peptides and amino-acids; and the third is *Ereptase,* which reduces peptones and polypeptides also into amino-acids, thus furnishing food for

the yeast during fermentation, during which process latent heat is liberated and the temperature of the wort increases.



SACCHAROMYCES CEREVISIAE

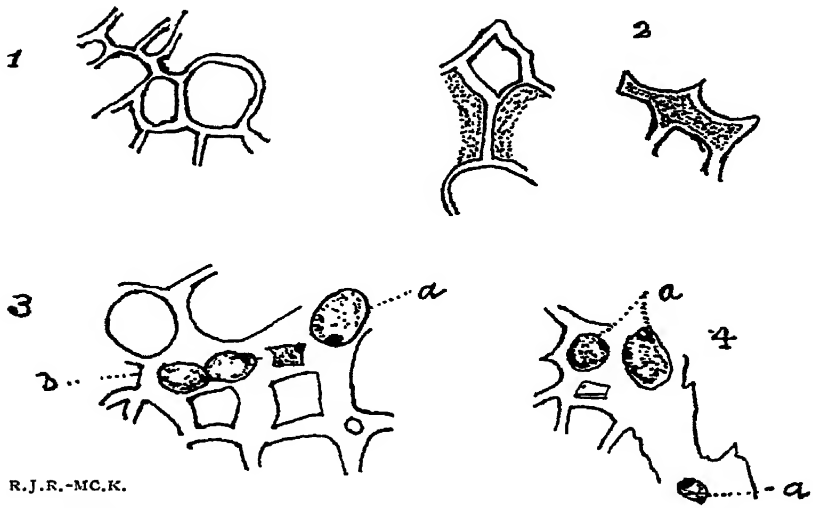
Yeast belongs to the genus *Saccharomyces*, which refer to micro-organisms capable of forming spores. Brewers and others technically engaged in the fermentation industries have classified yeasts as either



S. CEREVISIAE, BEGINNING OF FERMENTATION.
Nuclei (*n*) Metachromatic Corpuscles (*cm*)

"cultivated," *Saccharomyces cerevisiae* and its numerous varieties and sub-varieties which are the species originally and still employed in brewing, and on the other hand "wild" or abnormal yeasts such as *S. ellipsoidius* and *S. Pastorianus*.

Mention has just been made of the numerous races of *S. cerevisiae.* These differ enormously in their powers. Some are distinguished by their capacity for " attenuating " or reducing wort gravities by converting the sugars into alcohol and carbonic acid gas, and such yeasts invariably possess comparatively low propagative or reproductive powers. Others reproduce



YEAST CELLS, WITH NETWORK OF MUCILAGE

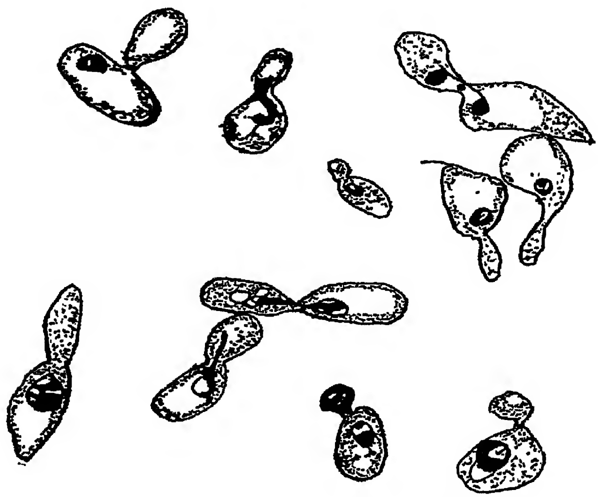
1, Portion of cells broken. 2, 3, cell wall altered by network (e.g. *a* and *b*): (*a*) vegetive cell, (*b*) asc with two ascospores.

themselves in brewers' wort very largely in excess of the amount " pitched " or added to the solution to be fermented, and yeasts of this type do not ordinarily reduce or " attenuate " worts to a low gravity. Yeasts with a small attenuating power are classed as *Saaz* type, whereas yeasts with high attenuating power are termed the *Frohberg* type, which can ferment more of the malto dextrins than the Saaz variety are capable of.

Further, certain classes of *S. cerevisiae* are known either as " slow yeasts " or " fast yeasts " from the speed at which they complete the process of fermentation. Slow yeasts are distinguished for their reproductive powers, while the marked characteristic of fast yeasts

is their capacity for attenuation. Moreover, these cultivated yeasts produce varying flavours, apart from those conferred by the materials employed, in the finished beers.

The true nature of yeast and fermentation was not definitely known until 1859, when Pasteur, in publishing the results of his classical and epoch making researches,

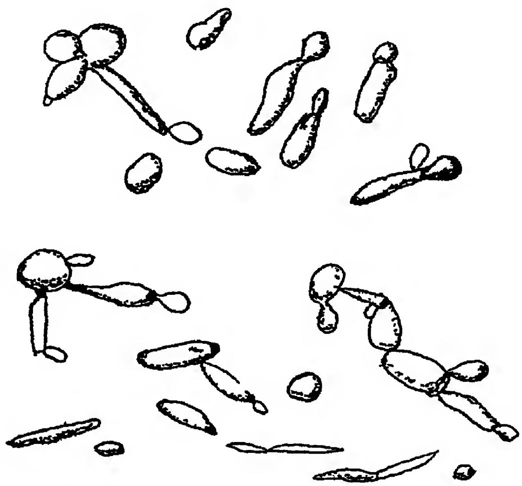


SACCHAROMYCES ELLIPSOIDIUS, SHOWING NUCLEUS

said : " My decided opinion on the nature of alcoholic fermentation is, the chemical act of fermentation is essentially a correlative phenomenon of a vital act, beginning and ending with it. I think that there is never any alcoholic fermentation without there being at the same time organization, development and multiplication of globules, or the continued consequentive life of globules already formed." Subsequently Pasteur showed that spontaneous fermentation was an impossibility, and he devised means for obtaining pure cultures. He proved also that yeast, as in brewery fermentations, added to a sugar solution in the absence of air, obtains the oxygen necessary to its existence and its power as a ferment from the sugar molecule which thus degraded,

or split up, yields alcohol and carbonic acid. Proceeding together with this change the yeast develops, absorbing for the purpose proteins, mineral matter, and some carbohydrate substances which form the structure and are required for the development of the life of the young cells of yeast.

At this stage Hansen, the great Danish mycologist, furnished with a knowledge of the methods introduced by Pasteur of obtaining pure cultures, commenced his



R.J.R.-MC K.

SACCHAROMYCES PASTORIANUS

investigations which led to the founding of the science of morphology, or the study of forms. He was able to isolate cells, and by inoculating cultures with these "single cells" he established the character and life history of numerous species which he has since classified. By this method of separation Hansen showed how one species differs in characteristics from another. He demonstrated that different races are not distinguishable under the microscope to an extent that warrants placing reliance for absolute identification on shape or form of cells, inasmuch as one class of yeast under unusual conditions of propagation may alter its original form to that of others. Hansen decided upon a method

which would eliminate this element of uncertainty in classification. He ascertained that each species at certain temperatures could develop spores (a minute grain in seedless plants which performs the functions of a seed), and that such type of yeast required its own particular temperature and period of development for spore formation. He further sub-divided the three varieties named into three sub-varieties, so that his list now embraced *S. cerevisiae I, S. Pastorianus I, II and III, and S. ellipsoidius I and II.*

Should it be required to know if a sample of brewery yeast contains one or other of the five wild types *S. Pastorianus I, II, III,* and *S. ellipsoidius I and II,* a culture of young cells is taken and the time noted at which spores are formed. This, of course, is an intricate process and its description obviously is beyond the limited scope of this book.

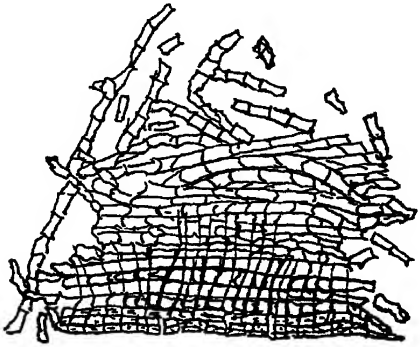
There is, however, one marked form which is more prominent than others in any particular microscopic field. In *S. cerevisiae* this form is round, the cells of *S. ellipsoidius* are elliptical, and those of *S. Pastorianus* are elongated.

Beer yeasts used in Great Britain are necessarily composite and are composed of the three main types named above, but although a brewery yeast may be made up of *S. cerevisiae, S. Pastorianus* or *S. ellipsoidius* the form of *one* of the three will be most prominent.

The brewer exercises extreme care in adopting every precaution to exclude from his fermentation an excess of *S. Pastorianus I,* which if present in an appreciable amount confers an objectionable flavour and also unpleasant odour to the finished beer, while both *S. Pastorianus III* and *S. ellipsoidius* give rise to a cloud or haze which is more likely to increase than diminish in the beer during storage. In addition the brewer is constantly on his guard to prevent the entry into his fermenting wort of acid forming—acetic and lactic acid chiefly—and other disease producing air-borne bacteria, which accounts for the fact that the entire

plant, premises and environment of a modern brewery of any importance is the acme of cleanliness.

The yeasts in fermentation multiply by budding, the



R.J.R.-MC.K.

BACTERIUM ACETI

bud breaking off from the parent cell after it has reached almost the size of the latter, when the young cells continue the process of multiplication. There are two

R.J.R.-MC.K.

OOSPORA LACTIS (FRESEN) SACE

general classes of brewery yeasts, "top" and "bottom." The latter, which deposits in the fermenting vessel, is employed on the Continent in lager beer brewing, and it is intended here to deal only with "top" yeasts, used in British breweries, which rise to the surface of the fermenting wort. It may be added, however, in connection with budding, that the buds of "bottom" yeasts

separate, while those of "top" yeasts cling together, chain fashion, in little colonies.

A further phase in the elucidation of the phenomena of fermentation was entered upon when G. Buchner, a German mycologist already alluded to, published in 1897 an account of his discovery under the title of "Alcoholic Fermentation without Yeast-cells." Buchner furnished conclusive evidence that fermentation is not directly associated with the life action of yeast cells but is a chemical action produced by an enzyme "Zymase" or yeast juice, free from cells, which can ferment dextrose into alcohol and carbonic acid gas without the production of yeast cells. Harden and Young, English mycologists, then proved by means of filtration that Zymase is composed of two substances. Curiously enough neither the filtrate obtained nor the colloidal residue when added *separately* to standard sugar solutions can induce alcoholic fermentation, but when the filtrate and the residue are brought together again the mixture can produce a fermentation precisely similar in activity and extent to that produced by the original Zymase. The active portion of the filtrate, therefore, was designated the co-enzyme, and the enzyme is a constituent of the residue remaining behind on the Chamberland filter employed.

This then, in brief, is the sum of our knowledge regarding the life history of brewery yeasts and their functions in inducing alcoholic fermentation in wort.

YEAST ANALYSIS

Mitscherlich		*Dumas*	
47·6%	Carbon	Carbon	50·6
6·0%	Hydrogen	Hydrogen	7·3
10·0%	Nitrogen	Nitrogen	15·0
·6%	Sulphur	Sulphur Oxygen Phosphorous Phosphates of Potash Lime and Magnesia	27·1
			100·0

CHAPTER II

SYSTEMS OF FERMENTATION

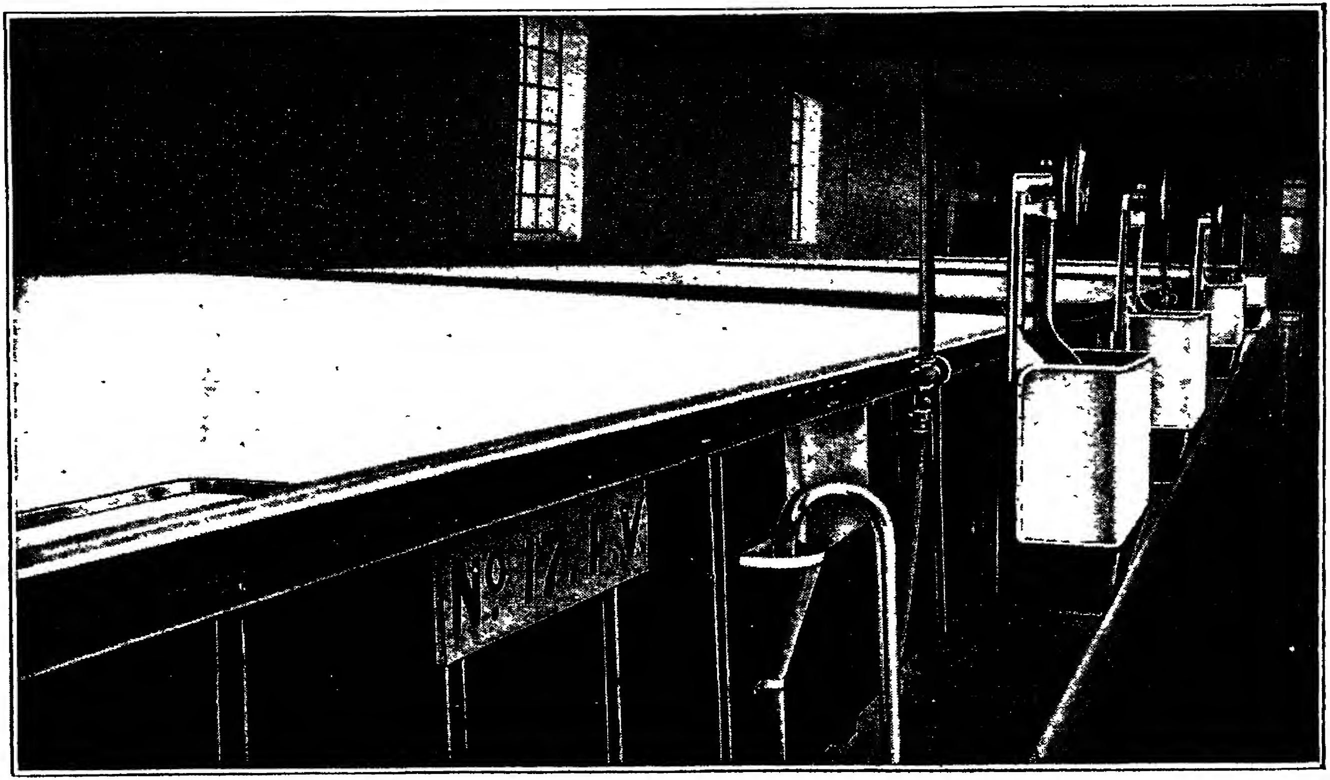
The Dropping System. This method is gaining in popularity as it offers distinctive advantages over other systems of fermentation. The wort is collected in an upper tun or vat at temperatures of from 58° F. to 60° F. When the specific gravity is reduced or "attenuated" to either slightly above or below half the original gravity collected, the partially fermented wort is "dropped" or transferred to a lower vessel where, at or near the conclusion of fermentation, reproduced yeast on the surface of the wort is skimmed at intervals of from 2 to 6 hours, as conditions necessitate, until the completion of fermentation ; the last rising of the yeast forming a protective surface covering until the contents of the vessel are "racked" into casks.

The "dropping" stage is reached at from 45 to 65 hours from collection dependent upon the constitution of the wort, the fermenting temperatures adopted, and the amount and type of "pitching" yeast used, for reasons already explained. The yeast rate varies in this as in other systems within wide limits according to the original gravity of the wort, ratio of hops, and proportion of adjuncts and other minor local regulating factors. For light mild ales $\frac{3}{4}$ lb. per barrel wort collected may suffice, whereas for heavy gravity bitter ales 3 lb. per barrel may be required.

Oxygen is a vital element in the successful conduct of all brewery fermentations. Pasteur made it clear that unless a yeast is subjected to the revivifying and invigorating action of oxygen, judiciously applied, it ceases to reproduce itself and becomes incapable of acting as a ferment. It follows, therefore, that directly the yeast has assimilated the free oxygen absorbed by the wort in its passage from the coolers to the collecting

vessel, measures must be taken to agitate the wort in order to liberate to some extent the CO_2 formed, and aerate the wort. In the system of fermentation under discussion, aeration is most effectively accomplished at the moment of dropping or running down the wort from the upper to the lower vessel which, moreover, yields the cleanest wort and purest yeast outcrops. The surface of the wort, when approximately half the original gravity has disappeared in fermentation, exhibits an accumulation of slummage or sludge composed of protein and resinous matters thrown out of solution, harbouring acid-forming bacteria, all of which is left behind in the upper vat when the wort is dropped. In addition to the advantages accruing from transferring a wort to another vessel at a stage which frees the wort from its maximum amount of sludge, the dropping system lends itself to a more thorough aeration and agitation and without waste than any other method, and at a stage when the benefits derived from the practice are best secured. The CO_2 accumulated from the decomposition of the sugars up to the dropping stage are then dissipated, the yeast cells are released from their asphyxiating environment of the carbon dioxide gas, and the oxygen absorbed to fill the place occupied by the former gas at once proceeds to exercise a revivifying effect on the yeast which carries the primary fermentation to a satisfactory completion. The vat contents are now spoken of as having "settled," after which the yeast in suspension (assisted by the cooling of the wort, either naturally or with the aid of "attemperating," i.e. water run through coils of copper pipes fixed in the tun) deposits, and the finished beer in a semi-clear condition is "racked" into casks. The entire process of fermentation and subsequent settling with its clarifying effect occupies from 5 to 7 days, so that a brew produced on, say, a Thursday may be racked, according to the system of fermentation and the controlling influence of many factors, on the following Wednesday, Thursday, or Friday.

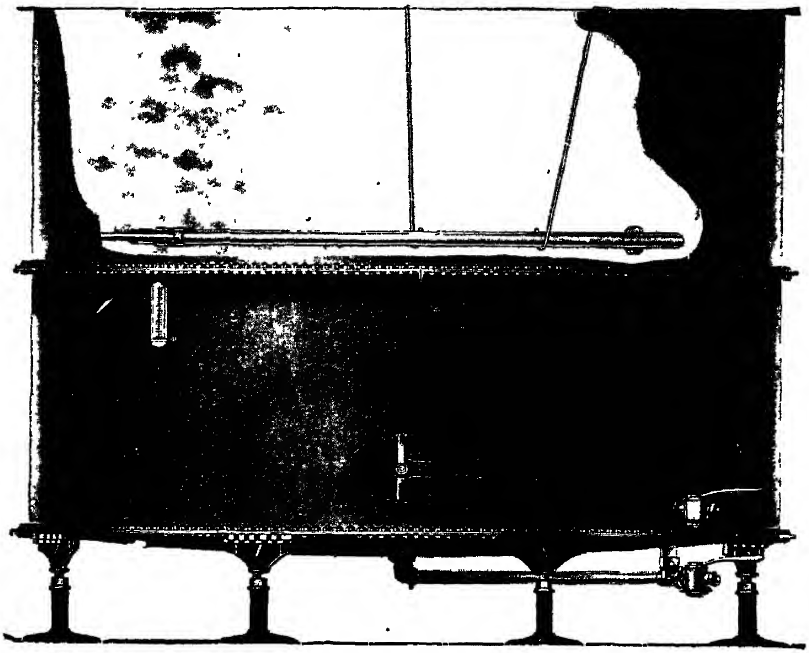
The Skimming System. This is a modification of the



FERMENTING VESSELS LINED WITH ALUMINIUM

(Aluminium Co., Ltd, London, S.W.18)

dropping method in which also the yeast is skimmed at the close of fermentation, so that the name is merely indicative of a system in which the wort is fermented, skimmed, and settled in single vessels at temperatures similar to that employed in the dropping method. By



METAL FERMENTING VESSEL, GLASS OR ENAMEL LINED

(*Enamelled Metal Products Corporation, London, W.C.2*)

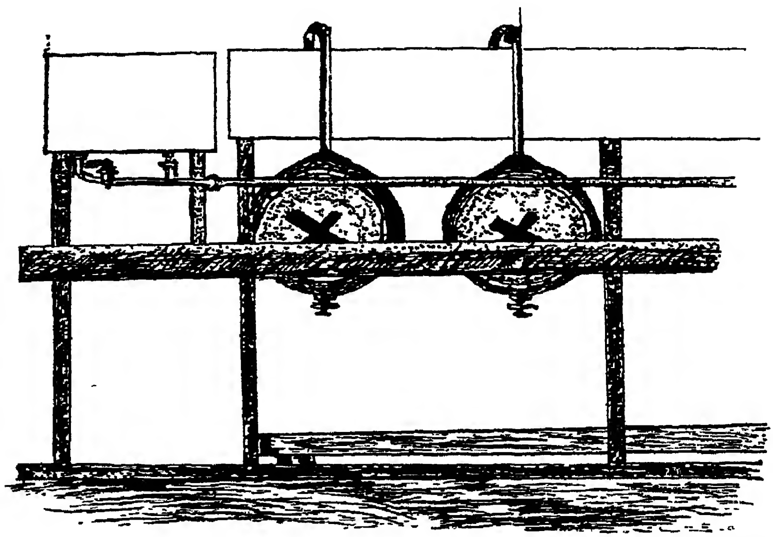
separating the wort as in the latter from the amorphous matter thrown out of solution in the upper vessel, refinement and purity of the ultimate product and the skimmed yeast is secured to an extent that is unobtainable when the entire fermentation process is completed in a single vessel. The amorphous matter mentioned consists mainly of resins and crude proteins held in solution by the saccharine constituents which, when fermented, render the former substances insoluble,

forming sludge. Apart from these advantages, with the dropping system a thorough expulsion of the gas formed is secured, followed by an efficient aeration of the yeast which supplies the necessary impetus to reproduction, and as the lower vessel is generally shallow a greater area for surface attraction is provided and the yeast is more readily expelled. With a single vessel correct aeration and agitation is not carried out, the CO_2 is not expelled effectively, nor is there the required limit of surface attraction to expel the yeast, especially if the single vessel is deep and consequently restricted in diameter. As a result of the cumulative effect of these adverse factors, the finished beer lacks refinement, flavour, and stability, and the purity of the yeast suffers from the presence of sludge which harbours micro-organisms of disease.

In the system under discussion " rousing " is conducted by means of an electrically driven pump which conveys the wort through a pipe or pipes reaching to nearly the bottom of the vessel. The pump throughout the operation continuously distributes the wort by means of a spray over the yeast developing on the surface of the vessel's contents. Rousing commences at from 18 to 24 hours after collection and is continued at frequent intervals, generally from 4 to 6 hours, until the skimming point is nearly reached. When the fermentation is completed the finished beer undergoes a settling period, sometimes similar in duration to that adopted in the dropping system, but more often the refining or settling stage is prolonged by 24 to 48 hours, after which the beer is run to a settling " back " or " tun " from which vessel it is transferred to casks. Settling or racking backs are, it should be added, a disadvantage in the dropping system, as the finished beer in the lower or skimming vessel is too clean and free from matters in suspension and CO_2 to permit of its further exposure with safety to atmospheric influences at this stage. It would absorb air with ease, and the micro-organisms present, in the absence of the inhibiting effect of carbonic

acid gas and the protective influence of yeast, would develop and lower the stability of the finished beverage.

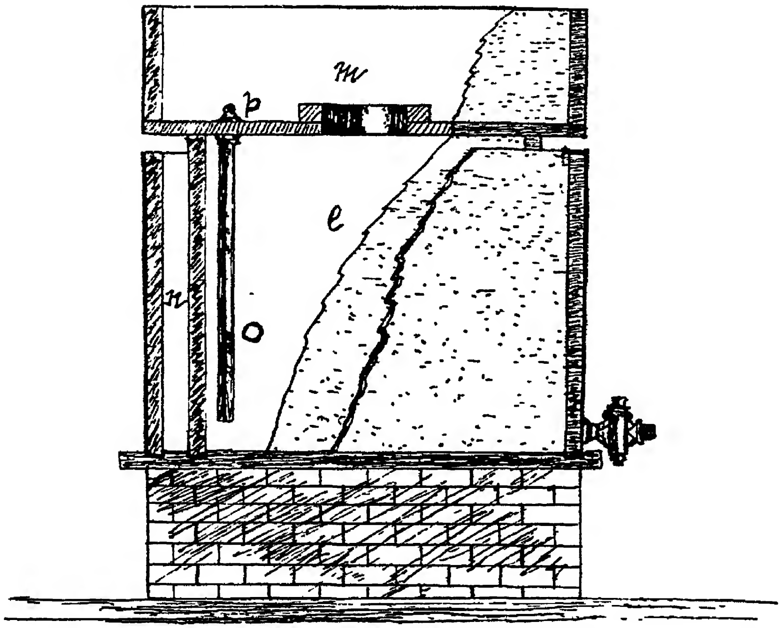
The Cleansing or the Burton Union System is carried out primarily on the lines of the dropping method, in that the first portion of the fermentation takes place in a large upper vat, and, when aeration is most required and prior to the formation of the true "yeasty head," the wort is run into Unions which comprise a series



BURTON UNION R.J.R.-MC.K

of casks of some 150 to 160 gals. capacity placed on their sides in rows. As fermentation proceeds the yeast is expelled through a pipe, fixed in the highest point of the cask, resembling the neck of a swan—hence the technical appellation "Swan-Necks"—and in the operation carries with it wort in suspension which is immediately replaced by a similar volume of bright beer, maintaining the Unions full, and drawn from a feed vessel controlled automatically by a ball-valve. When the unions are fitted with attemperators or the air in the cleansing room is cooled, fermenting temperatures are regulated and the system lends itself to abundant

aeration and a thorough expulsion of yeast and CO_2. Beers produced on the Burton Union method justify the term "cleansed" being applied to them, a designation descriptive of the flavour of the finished beers. The sub-division of the original bulk into numerous small vessels entails considerable labour, and involves a loss of beer very much in excess of that which accrues in other systems. Closely related to Burton Unions are



YORKSHIRE STONE SQUARE R.J.R.-MC.K.

(*e*) the square; (*m*) yeast-trough; (*n*) water-jacket, (*o*) orean-pipe; (*p*) valve.

Pontos, which are vessels of greater capacity placed on their ends. Instead of the yeast working through "swan-necks" an aperture of greater diameter is cut in the side of the Ponto, at the highest point and the vessels are maintained full by an automatic feed worker on the same principle as applied to Unions.

The Stone Square System. The application of this method is limited to counties such as Lancashire and

Yorkshire where slate or suitable " stones " are obtainable. A yeast peculiar to the system is employed, It is of the slow type and it is pumped every 2 to 4 hours, night and day without intermission, from the main bulk, in quantity that will occupy the available area in the upper portion of the " square " which, as will be observed in the illustration, divides the vessel. Here, the wort is subjected, at the intervals of time mentioned, to a thorough agitation with, of course, an accompanying agitation, after which the wort or " back drink " is returned to the bulk. The characteristics of " North Country Yeast " are high reproductive power and the capacity to assimilate types of soluble protein from the wort which are rejected by Burton, London, and, to some extent, Scotch yeasts. It follows that these stone square yeasts have poor attenuative properties, and while other yeasts yield a number of " heads " at the skimming stage, the entire reproduction obtained on the Stone Square system is removed with the initial skim. The predominating features of beer fermented by this method are stability," head " or foaming capacity, together with a pronounced mildness and roundness of flavour. On the completion of deposition or settling the contents of a number of stone squares are run into a racking back as in the Union and Skimming systems.

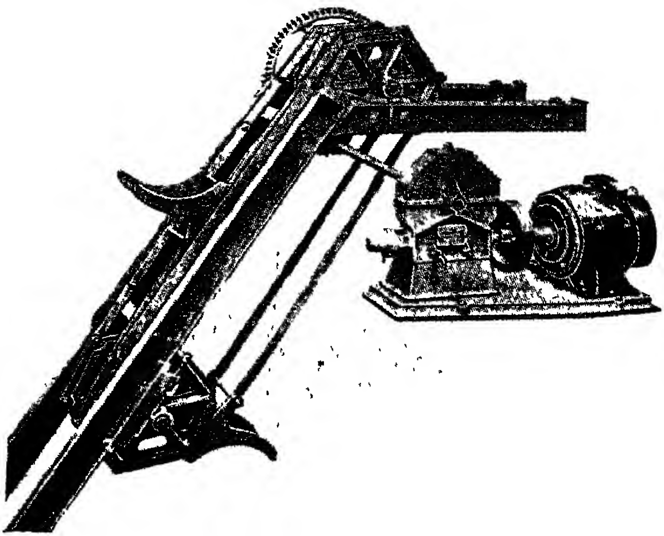
The Scotch System. As indicated in the description of the Yorkshire system, north country brewers do not regard the purity of an admixture of " heads " or separate yeast skimmings with the same degree of suspicion as do their southern confrères. In Scotland fermentation is carried on in an open vessel, and brewers " ayont the Tweed " were wont to run down a gyle to a settling vessel almost at the close of primary fermentation. No skimmings or heads were removed from the surface of the wort in the upper tun, and the almost completed beer was dropped at a stage judged to ensure the throwing up of a mere surface protective covering of yeast on the contents of the settling back. It followed that the yeast remaining behind in the collecting vessel, where

continued agitation and aeration of wort was applied in a manner similar to that resorted to in the skimming system was a mixture of the entire amount of yeast reproduced, together with the sludge. This was employed for subsequent "pitching" purposes and yet, although the practice is condemned theoretically on the ground that all but the middle skimmings are impure, Scotch beers fermented on this system have gained a reputation for a high general standard throughout the world. Indeed, at one time there were few Scotch brewers but exported a proportion of their production. In some instances, the original system of fermentation has been superseded by the "dropping" system. Scotch yeast is akin in fermentative properties to Yorkshire, although the former is less reproductive and more attenuative, and it accomplishes its task of primary fermentation at a slightly higher rate of speed. Both the Stone Square and Scotch yeasts, it should be noted, are types of exceptional vitality capable to a considerable extent of maintaining in check the efforts of alien and disease producing organisms to assert themselves. Moreover, the class of saccharomycetes we are discussing have the capacity of assimilating proteins of a class which, if remaining in the beer, would provide a suitable nutritive medium for the development of acid forming bacteria. Liberties can therefore be indulged in when employing "Yorkshire," and to a less extent with "Scotch" yeasts; but the brewer would court disaster who expected similar beer cleansing properties from yeasts of the Burton or London types, which belong to a finer and less robust genera endowed with lower reproductive power and a diminished capacity of resistance to infection.

The reduction of "specific gravity" or "attenuation" aimed at in the primary fermentation on any system is generally about one-fourth of the original collected. This, however, varies, and in some cases a third, or the mean between a third and a fourth, is considered the correct limit especially for mild beers and stout. Numerous factors, mainly dependent upon local requirements in respect to palate flavour and condition, regulate the

amount of unfermented residue which should remain in the finished beer.

Racking and Cellaring. Racking is the term applied to the transference of the completed beverage to casks when the necessary settling or clarifying period has been reached. Modern racking machines expedite the process and reduce labour. They are, moreover, designed to avoid agitation and aeration which produces a loss of



CASK ELEVATOR

(Gimson & Co., Ltd., Leicester)

beer by fobbing and results in the expulsion of CO_2 at a stage when the gas is most desired as a protective medium and should be carried forward to the cask. Light gravity mild beers are delivered to customers on the day, or within a few days, of racking, and this class of produce is known as "running beer." To better quality bitter ales hops—"dry hops"—of the highest class selected for their flavouring and aromatic properties are added at racking at the rate of from $\frac{1}{4}$ to $\frac{3}{4}$ lb. per barrel. These beers are then stored in cellars at about 55° F. for a period, regulated by their original strength, in order to develop secondary or cask

fermentation which, by reducing to a farther point the sugar residue the products of this subsidiary fermentation, enhances the general character of the beer in the direction of maturation. "Priming" or a sugar solution of high density is added to still further promote palate fullness, the gas evolved creates "condition," and together with the flavouring and aromatic properties yielded during storage by the saturation of the hops, the *ensemble* is a product much favoured by discriminating consumers.

The casks used in English breweries are: Hogsheads (54 gallons), Barrels (36 gallons), Kilderkins (18 gallons), Firkins (9 gallons), Pins (4½ gallons). In Scotland the smaller sized casks used are Ankers (10 gallons), ½ Ankers (5 gallons), and ¼ Ankers (2½ gallons). The casks used in Irish breweries are Hogsheads (52 gallons), Barrels (32 gallons), Kilderkins (16 gallons), Firkins (8 gallons), Pins (4 gallons).

Under present trading conditions the period available for the final clarifying of beer is not sufficient to permit of spontaneous clarification to the necessary point of brilliancy. To accelerate the process, "finings" are now added to all beers as they leave the brewery. "Finings" consist of a gelatinous diluted semi-solution of prepared isinglass (*Ichthyocoll*), obtained from the swimming bladder of the sturgeon and other fish of a similar genus. One quart, more or less, of the "Finings" is generally the quantity employed for clarifying purposes and the addition is carried out by injecting the prepared and diluted isinglass into the casks by means of a "pump" prior to forwarding the beer to customers.

CHAPTER III

THE STANDARDIZATION OF BREWERY PRODUCE—THE BREWER'S LABORATORY

An Essential Unit in the Equipment of a Brewery. The existence of a laboratory in a brewery is looked upon with suspicion by certain sections of the community as tangible proof that the produce of the establishment possessing this essential part of brewery equipment is in some measure composed of "chemicals." There are no "chemicals" employed in a brewery, unless the term can be correctly applied to the mineral substances added to the water for the definite and necessary purpose described in the chapter dealing with water, and for the general cleansing and sterilizing of casks, plant, and premises.

The assistance obtained from a knowledge of the results of the analytical examination of the various materials used in brewing, not only in assessing their commercial and technical value, but as a guide to the operative brewer in dealing with bulk quantities, was recognized by the majority of brewery and malting companies long before other industries adopted this system of "works control." The service rendered by a laboratory in the direction named is rightly regarded as essential to commercial success, especially in these days of high prices when so much depends upon the man controlling manufacturing operations.

The marketable value of barley and hops is based on ordinary physical examination applied by men of wide experience and ripe judgment. Rapid market fluctuations which necessitates bargaining "on the spot" do not permit of utilizing the advantages of analytical determinations or estimations. But a laboratory is of almost incalculable benefit in appraising the brewing worth of other materials and in maintaining immunity from many of the difficulties which beset the brewer.

A PORTION OF A BREWING ROOM AND LABORATORY

Malts, for instance, are purchased or contracted for at a price based among other factors on a pre-quoted moisture content on delivery. Should the water percentage exceed this figure by certain limits, a deduction is made from the invoice price. A clause of a contract may further stipulate "that the amount of extract yielded by the delivered malt be equal to that of the sample," and in the event of the extract (wort, or the saccharine infusion of malt which when fermented with other ingredients constitutes beer) obtained failing to reach within a definite percentage of that contracted for, as secured in the laboratory by what is termed a "Standard Determination," then a further reduction from the invoice price is also made. Analytical results, although essential and highly valuable, are not, taken by themselves, sufficient to furnish a complete valuation, technical and commercial, of malt. A correct interpretation of the chemical analysis must go together with a physical examination of the sample based on a practical knowledge of barley in general and, in particular, the type of grain from which the malt was prepared; information with regard to the various malting processes from the steeping of the barley to the unloading of the finished malt from kiln; and also the class of beer for which the malt is intended.

In a physical examination of malt, the main points are—

1. Uniformity in size of grain together with the presence or absence of foreign seeds or other extraneous matter, indicating correct or faulty screening and grading.

2. The length of the acrospire (see Malting) should be developed uniformly, extending to three-fourths the length of the malt. Experienced maltsters and brewers while fully cognizant of the value of chemical analysis pay due regard, as already mentioned, to the laboratory determinations, and combine these results with those obtained from a physical examination. They place reliance in some measure on the indications of the eye and palate in appraising the standard of malt, by such

further physical signs as the appearance of the malt and "combings" or "culms" (rootlets), the degree of modification (the change in the barley corn) from the tenderness or, on the other hand, the hardness ("steeliness") of the contents of the grain and the character of the flavour yielded on the palate.

The following is a typical chemical analysis of malt, as carried out in a brewery or maltings laboratory, to which explanatory notes are attached.

1. **Diastatic Capacity.** (The Power of the Enzyme Diastase which converts the modified starch in malt into sugars.) For malts intended for pale ales of high original gravity from 35 to 42 on Lintners standard. Malts for bitter beers of lower original gravity 28 to 30 on Lintners scale. Malt from foreign barley which is blended with British in the production of both mild and bitter ales should possess a diastatic capacity of from 26 to 28. Malt for mild ales in general and stout, under present conditions, 28 on the Lintners standard.

2. **"Tint" or Tintometer Reading.** (The Tintometer is an apparatus invented by J. W. Lovibond, of Salisbury, for measuring the tint of wort and beer.) Pale ale British malt 3·0 to 4·5. Foreign malt, to be used for both mild and bitter ales, 4·5. Mild ale British malt 6·5 to 9·0 under Lovibonds standard conditions.

3. **Extract.** (Matters in solution yielded from the infusion of crushed malt or grist forming, with other ingredients, "wort" which when fermented constitutes beer.) The amount of extract obtained is dependent on numerous factors, i.e. barley season, type of malt, methods of milling and brewing, skill applied, etc. The statutory presumptive minimum yield expected by the Customs and Excise is 79·2 "brewers pounds" per qr. (see preparation of wort), but the average yield of a modern brewery is considerably in excess of the standard named. British malts yield extracts from 90 to as high as 100 "brewers pounds." Foreign malts yield extracts of a somewhat wider range—as low as 80 and as high as 96 "brewers pounds."

4. **Soluble Albuminoids.** 2·3 per cent to 2·5 per cent.

5. **Ready Formed Soluble Carbohydrates.** (Sugars ready formed in malt.) They occur in malts in from 14 to 16 per cent. When in excess it indicates the adoption of high germinating or withering temperatures while the malt was undergoing preparation producing "forcing" conditions of growth, or loading to kiln insufficiently withered, or too low preliminary drying temperatures on kiln. When the ready formed sugars are present in malt in excess of 16 per cent the quality of the beer is adversely affected. Similarly the *minimum* limit is placed by authorities at 10 per cent.

6. **Moisture.** When the cured and finished malt leaves the kiln the moisture content should be 1 per cent. This moisture percentage increases with the length of time the malt is stored from the original 1 per cent to 3 per cent. When the water content reaches 5 per cent the malt is termed "slack," in which condition it is unfit for use and should be re-dried.

7 **Arsenic** (Statutory limit $\frac{1}{100}$ of a grain per pound for solids ; $\frac{1}{100}$ of a grain, expressed as arsenious oxide, per gallon for beer or wort.) Malts should not contain more than $\frac{1}{300}$ of a grain per pound. Many contain as low as $\frac{1}{500}$ to $\frac{1}{700}$.

Standardization of Beer Colours. (Method originated by the author.) The following method will ensure regularity of colours in any brewery. Make up a caramel priming sufficient in quantity to provide for several weeks' requirements. The colouring power of modern caramel is too intense to determine its tinctorial power by laboratory methods dealing in minute quantities. A barrel of water should, therefore, be employed to which 10 fluid ounces or $\frac{1}{2}$ pint of the caramel priming is added. Note the resultant tint of the whole in the $\frac{1}{2}$ in. cell (Lovibond), and record the factor for daily reference until the supply of priming is exhausted. Suppose that the colour value yielded by $\frac{1}{2}$ pint of caramel priming, diluted by its addition to 36 gallons of water, is 19 degrees or 38 per pint. Decide on definite tints at racking for

each class of beer brewed, allowing due provision for precise loss of colour during the primary fermentation. The colour of the wort should be determined as soon as practicably convenient after collection in the F.V. Suppose that the tint of a finished Pale Ale is desired to be $10\frac{1}{2}$ in a $\frac{1}{2}$ in. cell (Lovibond) with a provision of 2 degrees lost during fermentation, or a total of $12\frac{1}{2}$ degrees. Upon examining the filtered wort or centrifuged wort after collection suppose the tint was found to be only 9 degrees, showing a deficiency of $3\frac{1}{2}$ degiees per barrel. The quantity of wort collected may for the present purpose be taken as 100 barrels from which 3 per cent (or 2 per cent in instances where the yeast pressings are returned to the F.V.) for loss in volume during fermentation must be deducted. Obviously, therefore, there are 97 barrels, each of which is $3\frac{1}{2}$ degrees below the standard tint decided upon for that particular type of produce.

$$\frac{97 \text{ Barrels} \times 3{\cdot}5 \text{ degrees}}{38} = 8{\cdot}9 \text{ pints (say 9 pints)}$$

caramel priming required.

Analysis of Sugars, etc. In the analysis of natural sugars and saccharine substances prepared from starches, the brewer is provided with data by which he can assess their commercial and technical value in addition to their mineral and organic purity. He is furnished with the percentage composition of fermentable as compared with the unfermentable types of sugars present, the determination of the ash, nitrogen, moisture, extract, yield, etc., together with an estimation of the iron and colour. With regard to caramel it is necessary also to ascertain if the material is wholly unfermentable or, if fermentable, to what extent ; the tintorial or colouring power and the measure of its permanency, acidity, and the degree of solubility of the caramel in beer and alcohol.

In the analysis of hops the arsenic, moisture, tannin, resins (soft and hard) is determined and sulphur is tested for. The brewing value and purity of the preservatives offered to a brewer are also determined in the brewery

laboratory. It is also necessary from time to time to ascertain the original gravities of beers subsequent to fermentation. This applies not only to the brewer's own produce but, if need be, to that of his trade competitors. Disputes sometimes arise as to the genuineness of beer returned to a brewery. By ascertaining the original gravity of the beer, proof is furnished as to whether this corresponds within defined limits with the original gravity of the beer as collected prior to fermentation. There are two methods of determining original gravities in use in brewery laboratories, one is the "Distillation Process" employed by the Government Laboratory; and, when exactitude in result is not essential, an instrument known as an "Alcoholmeter" is employed. In a completely equipped brewery laboratory in which the whole time services of a fully-trained analytical chemist is retained, the entire analyses of water, malts, sugars, wort, and beer, the estimations of arsenic in brewing materials, and full advanced microscopic research work, yeast culture, etc., are undertaken. Water analysis to be of value must be carried out with considerable skill based on a wide practical knowledge of the intricate analytical processes involved. There are numerous valuable monographs published on water analysis to which interested readers can readily refer, and the general properties of typical brewing waters necessary for the successful production of types of ales and stout has already been dealt with exhaustively in the present volume under the heading of "Water."

Polarimeter. In the standardization of beers this instrument, of which there are many modifications, is employed for determining the contained solids and the comparative proportions of fementable to non-fermentable carbohydrates in brewery worts. Full directions for the use of the Polarimeter will be found in any work on Sugar Analysis.

The Microscope. Since the publication of Pasteur's epoch-making researches on fermentation the microscope

has been in everyday use in the modern brewery and maltings applied in many directions, but especially as a guide in controlling the vigour of the yeast and ensuring its freedom from the micro-organisms of disease. In this connection a study of "the Microscope in the Brewery and Malthouse" by Matthews & Lott (Bemrose, Derby), will amply repay microscopists in general.

The Forcing Tray is also among the essential units of brewery laboratory equipment, and with such an adjunct at his disposal the brewer subjects his produce to the "forcing" or abnormal conditions of development which accompany the employment of high temperatures, and can thus from a physical examination of the main contents of the flasks on completion of the pre-arranged forcing period, and the chemical and microscopic determination of their deposits is furnished with valuable information in respect to the stability of the beers and the classification of the yeasts and bacteria present.

Pure Air. Regularity and precision are thus primary principles which contribute to success in brewing, but although the brewer who is responsible for the finished article may be untiring in his efforts, and exercise all his powers to maintain uniformity, there are times when he finds it impossible to make every beer alike. He refers to the records of the details of each operation and finds every stage to have been conducted with as high a degree of exactitude as it was practically possible to secure. The malts may have been of the usual standard, as proved by the physical and analytical reports, and the hops, sugar, etc., may have been of the customary quality and type. The greatest care likewise had been observed to ensure that the brewing water was hardened to the required limit, and yet the finished beers, especially during certain periods of the year, vary in one or more points of general character. In the majority of cases this unsatisfactory condition of affairs is due to *infection.*

The most important recent discovery in connection with the standardization of brewery produce is the

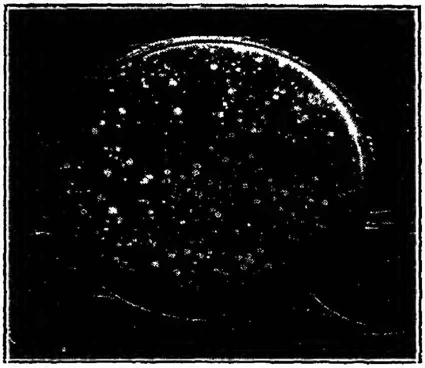
successful application of a new scientific principle in purifying, cooling, or heating the air of breweries. Bacteriological research has furnished proof beyond doubt that bacteria are incapable of passing through water and it is to the application of this hitherto unapplied scientific principle that the success of the new "Heenan" air purifier is due. The plant, as illustrated on page 126, is manufactured by Messrs. Heenan & Froude, Ltd., of Worcester and Manchester. The air to be purified is drawn from the atmosphere by means of a centrifugal fan. After passing through the machine the air leaves the purifier in a highly saturated condition at a temperature closely approaching that of the cooling water, and with re-circulated water the temperature of the purified air is only some 2 or 3 degrees F. above the wet bulb temperature. This ensures a supply of purified and cooled air, but should it be desired to heat the air a heater is fixed in the duct from the purifier outlet so that any degree of heat can be given. The advantages accruing from the cooling or, on the other hand the heating, of the air, lie in the direction of a considerable economy in the total period of time occupied in the refrigeration of the copper worts due to accelerated evaporation or intensified condensation.

The "Heenan" air purifier can be installed in any department of a brewery, but full efficiency is best assured when the machine is placed to command the hop-back, wort receiver, or coolers and the refrigerators. The wort as it reaches the hop-back is sterile, a condition, however, that is transitory. When the wort is subject to the essential process of "hot aeration" a rapid and considerable diminution in temperature ensues which is too low to destroy the causes of infection inseparably connected to a more or less extent according to the season of the year, with all cooling and refrigerator rooms.

From the exhaustive becteriological determinations obtained by the County Analyst of Worcestershire, the air, as it emerges from the "Heenan" air purifier, shows the unexampled efficiency of 100 per cent even with

atmospheres of abnormal impurity, and it follows that when the "Heenan" purifier is installed the wort remains sterile at collecting, providing, of course, ordinary precautions are observed to prevent the ingress of impurified air from outside sources.

The adoption of this purifier solves the problem that has harassed the brewing industry for generations, namely, that of securing precision of results in that the

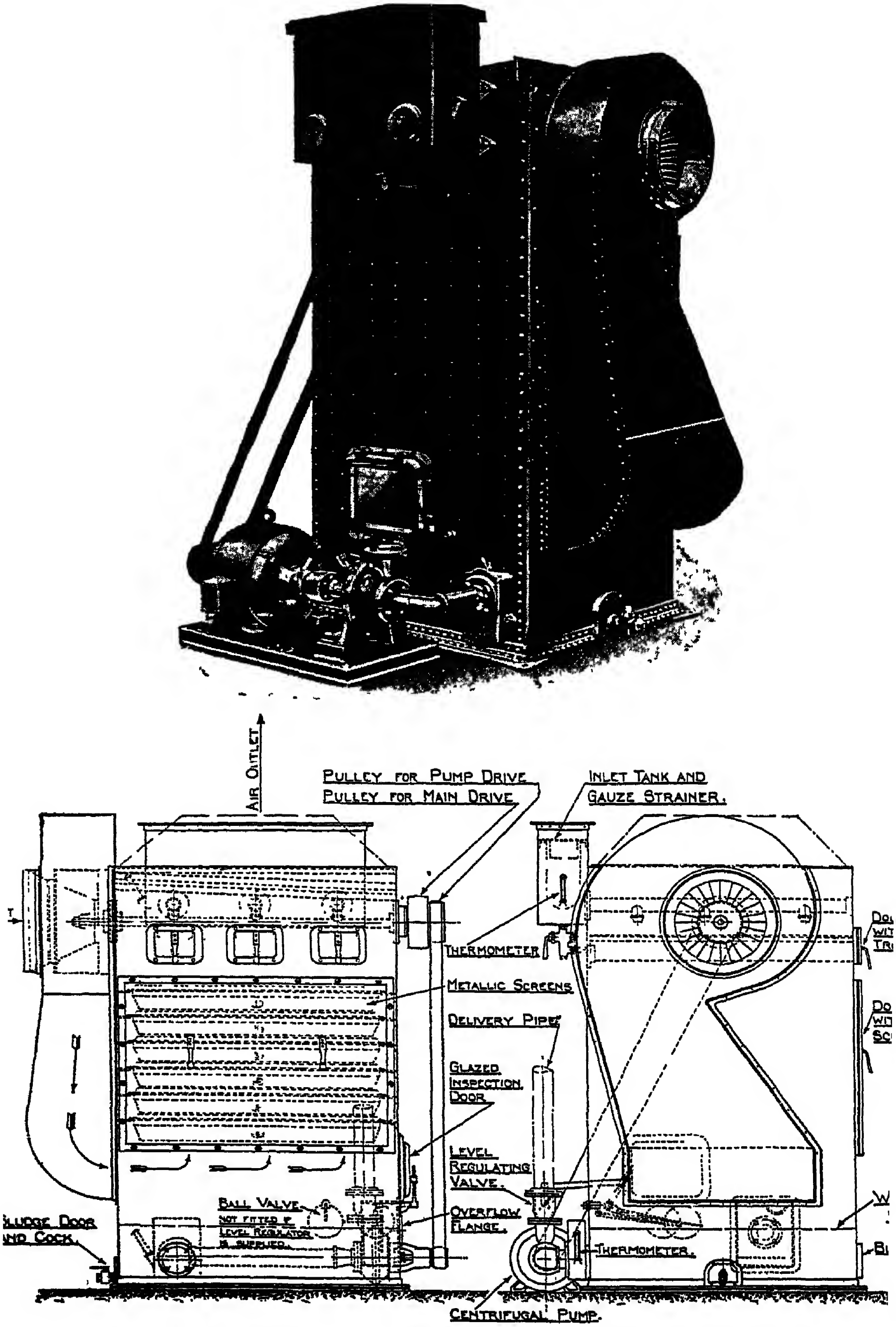


MICRO-PHOTO OF THE AIR AS IT ENTERED THE "HEENAN" AIR PURIFIER. THE FIELD SHOWN CONTAINS 880 COLONIES

MICRO-PHOTO OF THE AIR AS IT EMERGED FROM THE "HEENAN" AIR PURIFIER. THE FIELD SHOWN IS STERILE

beer reaching the consumer improved in flavour, of increased stability, and in brilliant condition. Such beers maintained in the forcing tray at high temperatures do not develop wild yeasts, bacteria, or moulds. Uncertainty associated with the bottling of beer on the natural system is removed, and under the "Heenan" pure air system wild yeast haze, excessive deposit, "floaters," and premature acidity of beer in bottle do not occur.

The pitching yeast is improved in such a measure that the necessity for "changes" is wholly obviated, Examined microscopically the yeast skimmed from



THE "HEENAN" AIR PURIFIER

worts collected in a sterile condition by the aid of a "Heenan" air purifier exhibit fields uniformly free from bacteria and other micro-organisms which adversely affect the general quality of the finished beer.

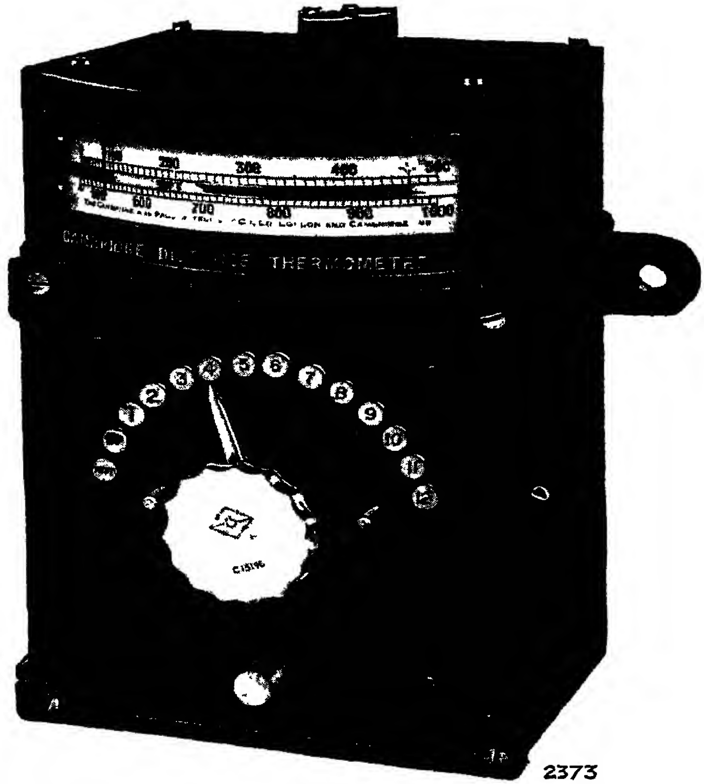
Whatever may be the cause of unsatisfactory beers, except in rare instances, the ordinary equipment of a laboratory will assist a brewer in his endeavour to ascertain the source of the trouble, and thus, as far as possible, ensure standardization.

To Ascertain the Source of Unsatisfactory Beer. Suppose, in the first instance, the cause of complaint was lack of brilliancy. A small volume of the beer to be examined is passed through a filter paper, and if the beer is rendered bright by the treatment then the cause of the cloudiness is yeast. This may be due to an excess of normal yeast caused by racking, or transferring the beer to cask, prematurely, or before a sufficient time has been allowed to elapse from the completion of fermentation, to ensure settlement or yeast deposition; or, on the other hand, the final attenuation (the diminution of original gravity) of the beer may have been too high when it reached the cask, in which the aeration at racking and the agitation caused by rolling the carriage cask, the beer would reach the customer in tumultuous condition.

If further proof is required a microscopic examination of a drop of the cloudy beer may be supplemented, and if the fault is due to excess of normal yeast, then the "field" will be so crowded with yeast cells as to suggest a "congested area." Should the period of rest given to the beer complained of and the attenuation both be satisfactory, then the cloudiness is due to either "wild yeasts" (see fermentation) the presence of which cannot be detected by microscopic examination, or imperfectly developed yeast cells. The presence of wild yeasts can be proved only by the formation of ascospores (membranous spore-sacs) in the interior of the cells. Different species of wild yeasts form spores, highly refractive spherical bodies which multiply much

more rapidly than do the ordinary cultivated varieties of yeast. The process is intricate and can be carried out successfully only in the hands of a trained chemist. But it may be found that the cloudiness is caused by badly developed yeast cells which can be readily detected and often cause turbidity. A sample of the beer is placed in a small beaker, and in the course of a few hours a white deposit of yeast cells will be thrown down. The trouble has arisen from the use of too meagre an amount of yeast at "pitching" (the addition of yeast to wort in order to ferment it) which places so much attenuative work on a low yeast rate that the organism cannot develop. The yeast will develop imperfectly also if the fermentation is conducted at unusually low temperatures, and the buds remain small The cure for beers rendered turbid through the cause just indicated is to rest the casks in a cold cellar for some time to allow the cells to reach maturity. Alterations in brewing methods will remedy matters in the case of normal yeast or badly developed cells, but with infection from wild yeasts where a pure air plant has not been installed, the faulty beer cannot be restored, and the only remedy is an entire change of yeast from an acknowledged pure source. In the event of the beer not filtering bright the cause is not due to yeast. A perfectly white saucer is then used, which is inverted, and in the bottom is placed a small quantity of beer to which is added two drops of tincture of iodine. If starch is present a blue reaction occurs, and if a red colour appears then the fault lies with the existence of high types of malto-dextrin (semi-unfermentable sugars). It may be that the sample of beer still resists our efforts to obtain brilliancy, but upon warming the sample in a test tube we succeed. Warmth will remove turbidity caused by both gluten and hop resin. To ascertain which of these substances is the cause of the trouble, some of the faulty beer is again placed in a test tube to which a few drops of ether is run in, and if this produces brilliancy then the turbidity was due to gluten. The proteins present

in wort may for the present purpose be divided into three classes. One is completely insoluble in cold water, another dissolves in cold water, and the third is soluble only at high temperatures and again goes into solution upon cooling. The last named are the glutens. It



DISTANCE THERMOMETER (12 POINT) INDICATOR

(Cambridge Instrument Co., Ltd., Grosvenor Place, S.W.1)

may happen that the beer we are examining resists all attempts hitherto applied to produce brilliancy. The beer in a test tube is then rendered slightly alkaline by adding a drop from a 10 per cent potash solution when, if brilliancy results, we have proved that cloudiness is due to hop resins.

Cloudiness may be caused by "finings" (a dilute

solution of isinglass which acts as a refining agent) which if suspended or fixed in the beer causes opalescence in extreme cold weather. By merely warming a sample of this beer in a test tube the finings or gelatine is precipitated.

Distance Thermometer. By employing this system of temperature registration the multi-point indicator shown on the previous page can be installed in the *Brewing Room*. The temperatures obtaining in heating tanks, mash tuns, coppers, refrigerators, fermenting vats, etc., and on malt kilns, can be ascertained immediately by merely turning the indicator switch to the "point" connecting with the thermometer in any room or vessel. The instruments are calibrated in either Fahrenheit or Centigrade degrees, and the scales may be made to commence or terminate at practically any temperature required.

CHAPTER IV

BOTTLING

BOTTLING is carried on under three systems—the natural process, the "Carbonating," and the so-called "Non-Deposit" method which was introduced into this country from the United States.

The Natural Process. The beer is matured in cask in the manner already described. For heavy beers an interval of from 5 to 7 weeks, according to the season of the year, is allowed to elapse between the date of brewing and that of bottling, and a correspondingly shorter maturing period is required in the case of lighter gravity beers. When bottled a further interval is necessary in order that the contents of the bottles generate "condition" and develop true bottled flavour and aroma. This period varies also with different beers and corresponds approximately with the length of maturing period in cask. The following hints on bottling "Bass" may be regarded as typical of the methods practised by successful bottlers.

"In summer, beer is generally ready for porousing within 24 hours after delivery. In winter, time must be given for fermentation to develop actively before inserting porous peg. The ale should be bottled bright and sparkling, not flat, about 7 to 10 days after stillaging in summer, and according to cooler temperatures in winter. To secure bottle condition 'Bass' must be kept in bottle before sending out: in summer for not less than 5 weeks, in winter for not less than 7 to 8 weeks. Stow the casks immediately they are received. Have the back rail of the stillage 2 to 2½ inches higher than the front rail; this will reduce the amount left in the cask when tilting takes place. Always use dry bottles and good quality corks. Do not steam corks. Suspend then in warm water for a minute or two.

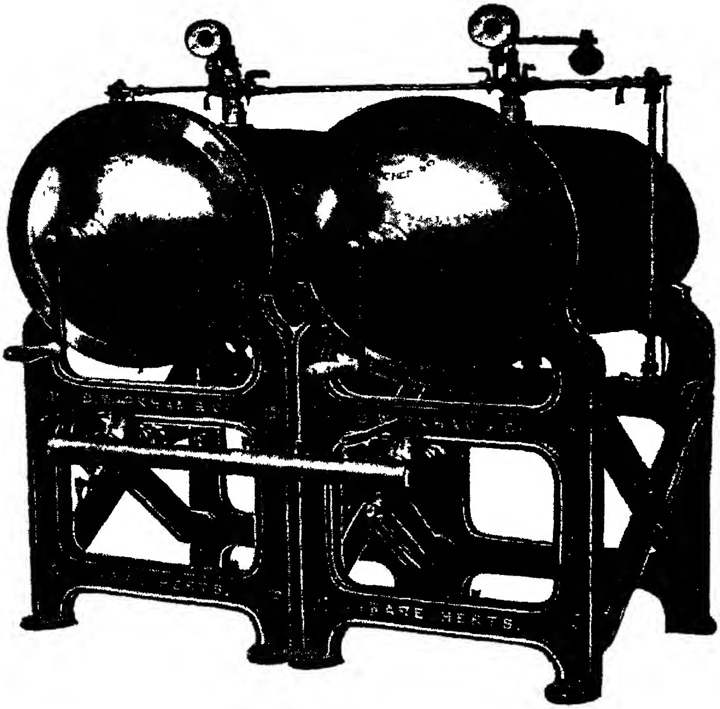
This is quite sufficient for the purpose of lubrication when the cork is driven into the bottle. Fill cork bottles 2 inches from brim of bottle. If an inch and a half cork is used this leaves only half an inch space. Fill crown cork bottle within half an inch of the brim. The less air space the better results." The natural

(Messrs. Bass, Ratcliff and Gretton, Ltd., Burton-on-Trent)

process produces the acme of bottled beers. Consumers only complain of the loss of beer resulting from the deposit formed in the bottles.

The Carbonating System. In the natural process just described the carbonic acid gas is slowly generated, conferring a distinctive flavour, aroma, and other attributes as the result of maturation in bottle and also the CO_2 being virtually in true solution. Obviously the natural process involves considerable capital

expenditure in beer and in bottles, etc., which have to be stored for long periods, and the cost of labour is also high. To lessen the prime cost of bottling under the headings named, the carbonating process is adopted.



BARREL SIZE BEER CARBONATOR

(Messrs. D. Wickham & Co., Ltd., Ware)

It consists of the addition of artificially prepared CO_2, or much preferably this gas collected from the surface of brewing fermentations. With artificial carbonation the gas is merely suspended in the beer, but the system has the advantage of the absence of deposit in the bottles if their contents are consumed within a short period of bottling. The principal factors to be observed in bottling by the carbonating process are: The beer should be brewed under such conditions as will ensure

a minimum proportion of proteins in the finished article. A beer which has undergone secondary or cask fermentation is preferable to a new or "green" beer, both in respect to deposit and flavour, and it should be of a quality that will clarify spontaneously. A beer so treated will compare, it is claimed, so far as the flavour conferred by age is concerned, with beer bottled by the natural process. The beer should not be fined if it can be avoided, but if fining has to be resorted to no more isinglass should be used than is absolutely necessary to ensure brilliancy. If an excess of finings is used and the beer does not contain sufficient tannin to coagulate such quantity of isinglass, the beer may become brilliant yet containing finings in solution, and these beers on being carbonated will throw down a flocculent deposit. This is a sure indication of finings having been used in excess.

The temperature of the cellar where the beer has been stored or is fined should be lower or, any rate, not above that of the bottling store, and this again should be lower than the consumer's cellar, in order that the beer may not be chilled or subjected to a temperature below that obtaining previous to carbonating.

THE PRINCIPLES OF CHILLING, OR COLD PRODUCTION BY MACHINERY

To understand the purpose of the machinery employed in chilling beer, a knowledge of the principles upon which the process depends for the production of cold is rendered necessary. Although a machine using ammonia is here referred to, the reactions which occur are similar when carbon dioxide, or ether, are used. The ammonia gas (not the solution of ammonia or liquid ammonia of commerce) is contained in the pipes, etc., of the machine and continually undergoes the cycle of operations to be described, except for a slight loss from leakage, which must be replaced occasionally.

Referring to the diagram, the ammonia gas is compressed by the pump through the pipe *A* into the pipes *B*, termed the refrigerator, over which trickles cold water. The effect of compressing the gas is to *heat* it, the surplus heat being removed by the water. The

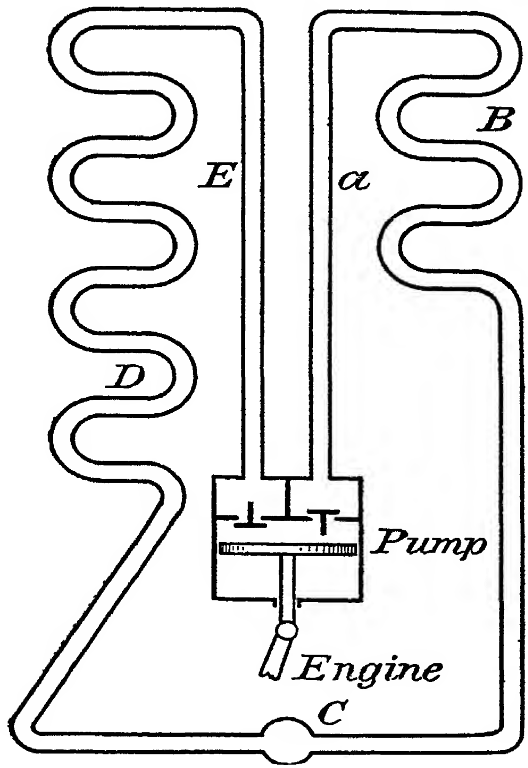


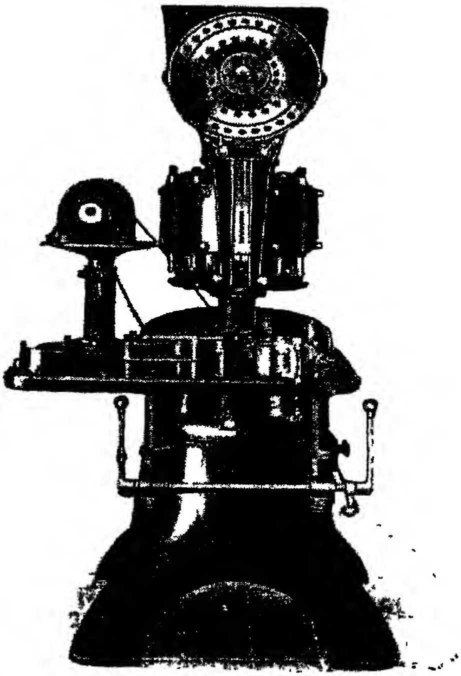
DIAGRAM SHOWING PRINCIPLES OF COLD PRODUCTION

compressed gas thus absorbs, or acquires, the temperature of the water used. When the pressure amounts to 100 lb. per square inch at ordinary temperatures, the gas liquefies, and in so doing gives out heat which is also removed by refrigerator water. Liquefied ammonia issues from the bottom of the refrigerator and passes the regulating valve *C*. Having passed this valve, it proceeds inwards to the coils *D*, from which the pump is continuously pumping it. In doing so, the pressure

in D is decreased and the liquefied ammonia *boils*, becoming gas. For a liquid to become a gas it must take up heat, and the heat required in this case comes

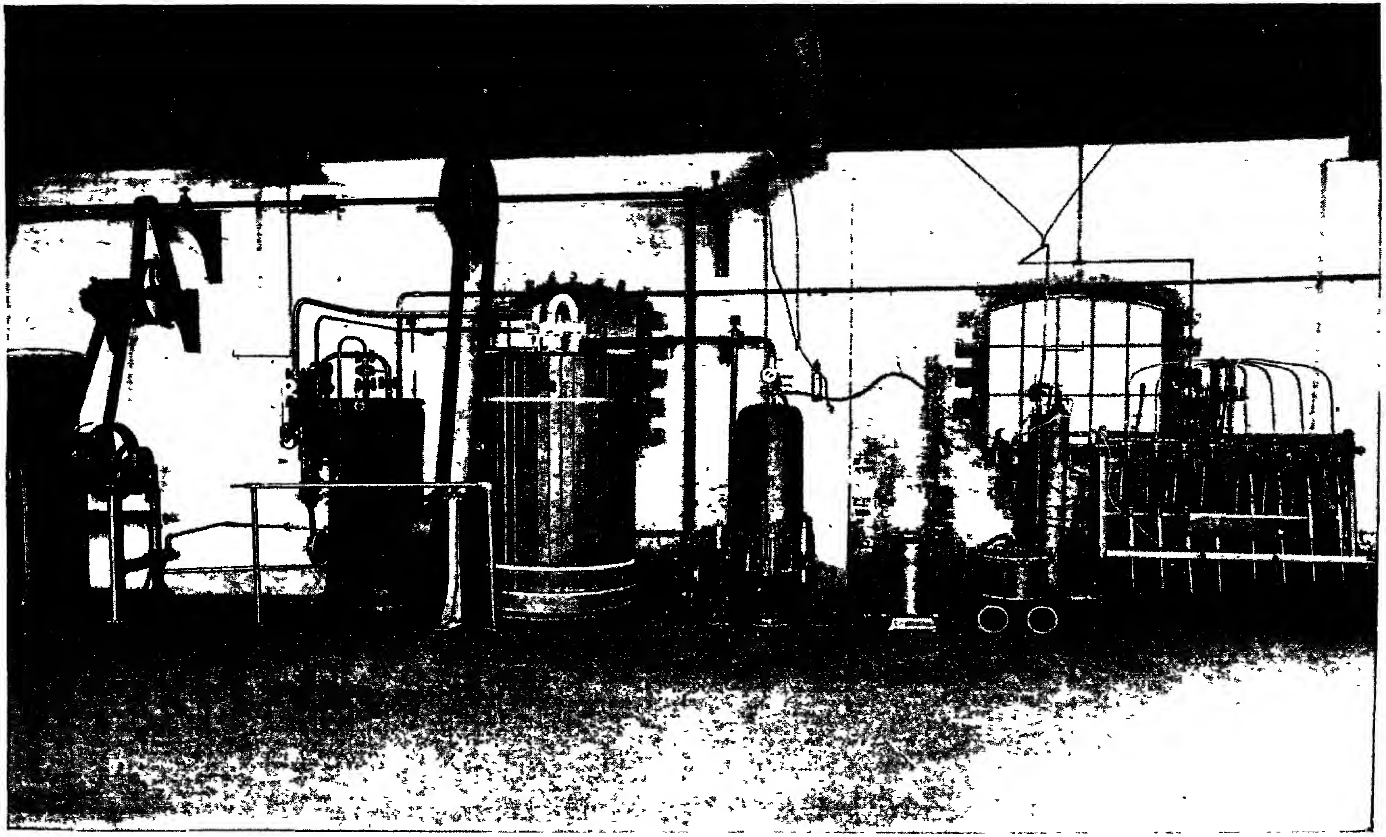
CROWN STOPPER OR CORK

from whatever the coils D are immersed in. If D be immersed in water, the temperature of the water is consequently *lowered* ; if D be in brine (a strong solution



HIGH SPEED CROWN CORKING MACHINE
(*Crown Cork Co., Ltd., Southall*)

of $CaCl_2$ which does not readily freeze), a temperature many degrees below freezing point can be attained. Cans of fresh water immersed in this cold brine furnish solid blocks of ice. The gaseous ammonia from D



COMPLETE QUICK CHILLING, FILTERING AND BOTTLING PLANT
(Messrs. D. Wickham & Co, Ltd., Ware)

passes by the pipe *E* into the pump, by which it is forced through the above cycle again.

The Chilling and Carbonating System. The principle upon which this more elaborate process is based is to subject the beer to the influence of extreme cold or "chilling"—temperatures 28° F. to 32° F. are employed —which throws out of solution those resinous matters and proteins of changeable character which form a deposit in beer bottled on the natural system. In the process under consideration, at the conclusion of the chilling stage, the beer together with the CO_2 in solution is passed through a filter and bottled.

A plant for quick continuous chilling and carbonation of beer is illustrated. This consists of a circular copper container fitted with brine coils, the bottom of the container being lagged and acting as a sump. The beer is delivered into the head of the machine by a pump (the capacity of which may be regulated by the attendant) and flowing down from coil to coil speedily chills, and being in a finely divided state rapidly absorbs the CO_2 with which the container is maintained charged at a definite pressure. The advantages claimed are that the beer, being in such a fine state of division in close contact both to the chilling coils and the carbonic acid, lends itself to chilling, and the absorption of CO_2 enables the machine to carry out this dual process at its maximum rate and permits of a continuous process. The machine is easily regulated, and is capable of chilling and carbonating large quantities. It can be easily dismantled and cleaned as the upper portion of the copper container is detachable. This exposes the interior of the Chiller which can then be easily cleaned.

Chilling and Carbonating on the Slow System. This method produces results superior to the fast process, although the initial outlay in casks or tanks and the cost of their subsequent maintenance and in working expenses is considerable. By this method the beer is allowed to develop full secondary fermentation in specially constructed casks capable of withstanding

the high pressure which is generated, or more often 40 to 50 brl. enamelled metal tanks. When casks are employed they are then removed to a cold storage where the CO_2 liquefies and the turbid beer in consequence is rendered flat. It is then under pressure passed through a filter and the brilliant filtrate bottled. The bottles are subsequently transferred to a store maintained at a temperature of 55° F., at which the carbonic acid gas present returns to its original form and the beer is in a condition ready for consumption. In many instances the beer is delivered to the customer directly after bottling, the bottler relying on the knowledge that the ordinary higher atmospheric temperatures will serve to liberate the CO_2 in an increased volatile condition.

Refrigeration. The following calculation shows the capacity of a refrigerating machine or chiller to cool down a given quantity of wort or beer in terms of barrels a given number of degrees—

N = Number of barrels.
W = Weight per barrel.
8 = Specific gravity of wort or beer.
h = Specific gravity of wort or beer.
t = Initial temperature of wort or beer.
t_1 = Final temperature of wort or beer.

[1] Tons of refrigeration $= \dfrac{360 \times 8 \times h \times N(t - t_1)}{318{,}080}$

[1] One ton of refrigeration = 318,080 B.T.U.'s, i.e. the amount of heat that would be required to convert one ton of ice at 32° F., into a ton of water at 32° F.

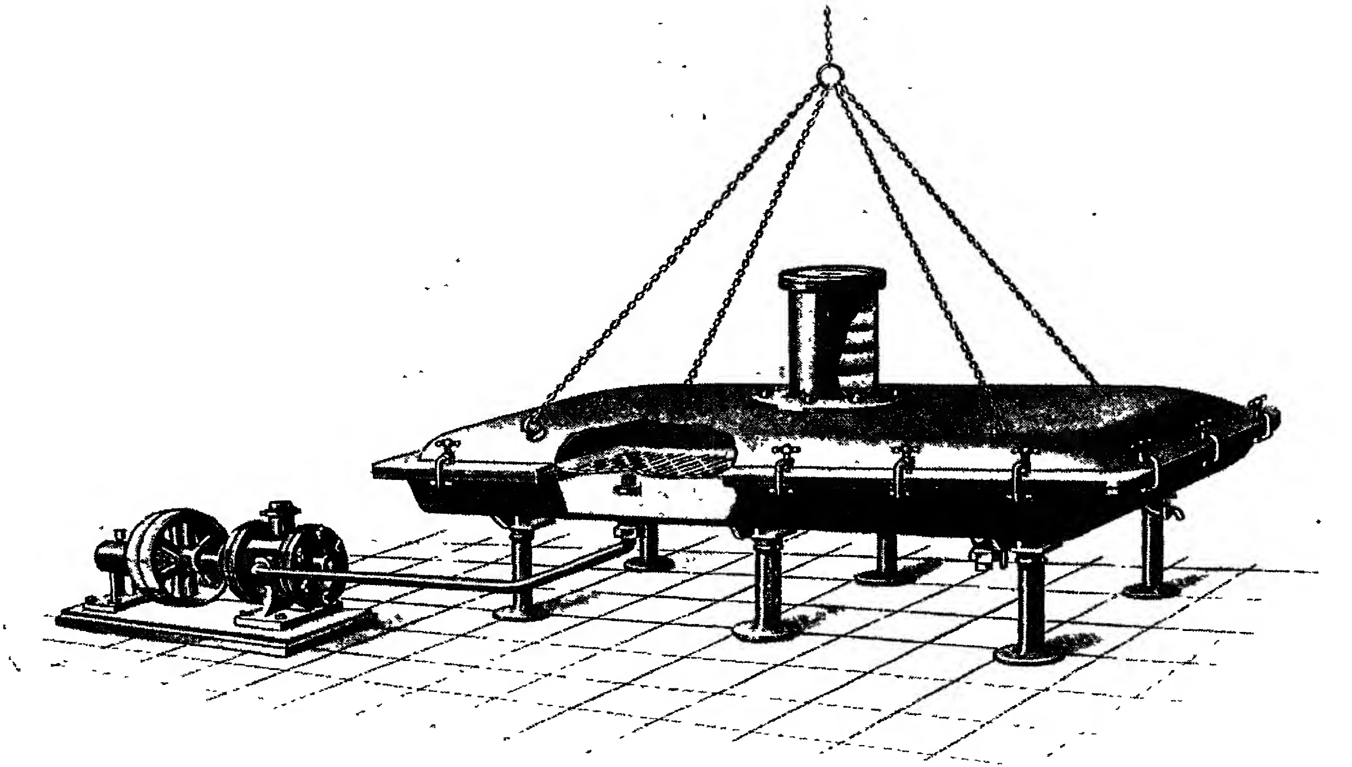
CHAPTER V

THE PRINCIPAL BREWING AND MALTING BY-PRODUCTS

THE by-products of the maltings and the brewery are various, but the main articles are culms or combings (kiln dried malt-rootlets), brewers' grains, or " draff " as it is known in Scotland, together with compressed yeast.

Culms or Combings. On analysis they yield the following composition: Protein 21·49 per cent, carbohydrates 46·39 per cent, ash 3·02 per cent, moisture 10·70 per cent, fibre 18·40 per cent. The ash of malt culms contains lime in a small amount, but phosphoric acid and potash is present in large quantities. Culms are used for pig and cattle feeding purposes, and when mixed with yeast it forms a valuable commercial yeast-food. Kiln dust, so-called, consists of the culms which have dropped through the holes in the kiln floor tiles, and are in consequence mixed with coal dust, serves as an excellent surface fertilizer for lawns and gardens.

Brewers' Grains. These are disposed of wet after being drained and removed from the mash-tun, and in the opinion of the Board of Agriculture brewers' grains are the cheapest flesh forming food on the market. The Journal of the Board of Agriculture (July, 1915) states: " Wet grains contain all the husk of the barley, a considerable portion of which is digestable, and also the bulk of the albuminoids (proteins) or flesh forming substances present in the original grains. . . . . it is the cheapest per food unit and is largely used for feeding dairy cows." Brewers' wet grains compare well with the best pasture which has an albuminoid ratio of 1 and 4 and moisture varying with the weather from 72 to 84 per cent (grains 78). The high proportion of proteins in brewers' grains make it an ideal food for milking cows and fattening animals. Leaflet No. 79 issued by the Board of Agriculture states: " The albuminoids (proteins) ratio required by a sucking animal



PURE AIR ATMOSPHERIC YEAST PRESS
(T. R. Shercliff Coy, Ltd., Burton-on-Trent)

is about 1 to 4 as in new milk ; by milking cows and half-grown cattle, sheep and pigs growing and fattening at the same time 1 to 5 and 6 ; and by an adult animal simply fattening or by a working horse, 1 to 8. Six qrs. malt = 1 ton wet grains.

Brewers' grains are also dried (10 per cent moisture), in which condition they lose nothing of their original nutritive value and will remain sound for an almost indefinite period, and can be stored to wait for a favourable market if need be. One ton of "dried grains" can be produced from 27¼ qrs. wet grains.

Compressed Yeast. The yeast skimmings are pressed and the bright beer filtrate is returned to the fermenting vessel. The compressed yeast is not employed for baking purposes to any considerable extent, as the bakers object to the bitter flavour yielded by the adhering hop constituents. This can be removed by washing, especially with ammonia carbonate, or phosphoric acid, sodium sulphate and ammonium tartrate, but few brewers treat their surplus yeast in the manner described. Compressed yeast has medicinal properties ; it is used for tanning ; and in conjunction with malt extract it is used as a food for invalids. Dried by a special process to a fine powder it yields a substance similar to meat extract in flavour and dietetic properties.

The yeast press illustrated on page 141 consists of two parts, the lid and the bottom tray. A filter cloth, on which the yeast is poured, rests on a false bottom and is securely held between the tray and the lid by means of an air-tight rubber joint. A slight vacuum is created under the cloth by means of an air pump from which the yeast is pressed into the tray. All the air that comes into contact with the yeast passes through the air filter and consequently all fear of aerial contamination is eliminated.

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